

SCIENTIFIC REPORTS

OF THE

Imperial Agricultural Research Institute, New Delhi

For the year ending 30th June 1939



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FOR THE YEAR ENDING JUNE 30, 1939

REPORT OF THE DIRECTOR

(B. VISWA NATH)

This is the third report after the transfer of the Institute from Pusa to New Delhi towards the end of the year 1936, and is the second report after growing of crops on the agricultural land was commenced.

The season during the year under report was very unfavourable. The monsoon was late. The total rainfall on the station at Delhi was 10·38 inches as against 20·30 inches of the previous year, which was much below the normal. Except for a few days, dry and drought conditions prevailed throughout the two crop seasons. All *kharif* (summer) and *rabi* (winter) crops, except pulses, had to be sown and maintained with the aid of irrigation.

The land at Delhi had again yielded excellent crops in the second year, and in every case the yields were larger than those in the first year. The removal of the surface soil to depths varying from one to four feet in the process of levelling had been of no consequence, and under the prevailing climatic conditions the soil was able to recuperate in a marvellous manner. Soil uniformity, as judged by crop growth, was also evidenced much faster than was anticipated.

The transfer of the Institute to Delhi has given the Institute a central and more easily accessible location than at Pusa. The Institute has begun to attract research workers and highly qualified students in larger numbers than before. These developments are gratifying and promise greater potentialities in the further development of the science and practice of Indian agriculture. The Institute can expand its activities and serve the cause of Indian agriculture in proportion as its financial and scientific resources are increased. The transfer has, however, not increased, in any degree, the resources of the Institute for coping with the increasing demands made on it in research and post-graduate training. A modest scheme of expansion was approved towards the end of the year under report, and it is hoped that it will soon receive financial sanction and come into operation.

The Agricultural Section has facilities for field research at Delhi and Karnal. Having completed the lay-out at Delhi and commenced cropping tests, attention was directed to the layout of the farm at Karnal, where drainage

was the chief item to be attended to. During the year under report considerable progress was made with the drainage scheme. Arrangements have been made for carrying out at Delhi most of the cultural and experimental work involving animal power and at Karnal for work involving the use of machinery. Thus, in addition to the seed multiplication of improved varieties of crops, the work at Karnal is the practical large-scale testing and expression of the work and results at Delhi. Power farming in India has very little scope at present, but there may arise the necessity for data on the subject if and when schemes of large-scale co-operative farming come up for consideration. Besides, for an extensive station like Karnal power farming is more economical.

I. INTRODUCTORY

As a central research organisation, the primary function of the Institute is to carry out fundamental research and post-graduate instruction that are usually outside the scope of provincial and state organisations, and also to provide facilities for other research workers to continue work on their problems of research. The reports by the Heads of the different Sections of the Institute record steady and satisfactory progress in these directions, in spite of the handicaps occasioned by the adverse season and restrictions on expenditure.

The programme of work carried out in the different Sections of the Institute is based both on the demands made by current and pressing problems and on the trend of future developments, and include research and investigations on problems concerned with soil fertility, soil cultivation, evolution and nutrition of crops, and the protection of crops from damage by disease and by insects in the field and in storage.

The work of the year under report will be briefly reviewed here. Details will be found in the reports of the Heads of Sections which are printed in continuation of this review.

II. RESEARCH AND INVESTIGATIONS

1. MIXED FARMING—CROP AND ANIMAL HUSBANDRY

The best and the simplest way of building up and maintaining the fertility of Indian soils lies in mixed farming which is the judicious blending of crop and animal husbandry. These two branches of agriculture are interdependent, and peasant farming will prosper in proportion as the land grows sufficient crops for maintaining the farmer and his cattle and the latter maintain the fertility of the land. The theory and practice of mixed farming continued to receive attention as a major problem of investigation.

(a) *Crop Husbandry*

An area of 334·57 acres was worked on a mixed farming system for the production of food and fodder for the livestock, while 66·32 acres have been set aside for permanent and long-term experiments. In the rotation of crops, as followed on the mixed farming area, ample provision has been made for the increase or maintenance of fertility of soil by fallowing, green-manuring, growing of leguminous crops in rotation and application of organic manures.

The yields obtained with principal crops, and compared below with those recorded last year, show that the soil is responding well to the treatment it is receiving :—

	Average yield per acre in maunds (82·3 lb. = 1 maund)	
	1938-39	1937-38
Jowar—Green fodder	272	171
Berseem—Green fodder.	397	486
Oats	29	27
Wheat—P. 165	19	17
Wheat—P. 114	19	14
Barley	43	30
Gram	11	12
Peas	17	15

Fodder investigations.—Attention was continued to be paid to the important problems of fodder crops, such as production of pure berseem seed at a cheaper rate, water requirements of berseem and the yields of alternative fodders. The maximum quantity of berseem seed was obtained, both at Delhi and Karnal, when the crop was left for seed after the first cut taken in the beginning of January. Owing to the early break of monsoon the quality of seed was badly affected, and it appears that this will be a serious limiting factor in the production of berseem seed in the plains of India. The results of irrigation experiments with berseem indicate that irrigation at an interval of 12 days is as effective as that of 8 or 10 days. The undermentioned six *rabi* fodder crops were tested for their yield in six randomised blocks, and berseem, while requiring the largest number of irrigations, gave the highest yield. Berseem was cut once each month from December to May, and yielded green fodder throughout the cold weather, which cannot be said of any of others listed below :—

Fodder	No. of irrigations given	No. of cuttings	Mean yield of green stuff per plot in lb. (·0105 acre)
Berseem	21	6	888·8
Senji (<i>Melilotus</i> sp.)	12	2	225·5
Methra (<i>Phaseolus</i> sp.)	10	2	202·7
Kerao (Peas)	6	1	398·0
Khesari (<i>Lathyrus</i> sp.)	6	1	314·8
Barley & Kerao (Peas)	7	1	401·5

Machinery and implements.—Ploughs of different types from different parts of the country were collected. Fifteen of these were subjected to preliminary tests on draft when pulled by bullocks. The tests were carried out by means of a recording traction dynamometer. Among tractors, the W. D. 40, McCormic Deering type, and the Hanomag 55 H. P. crawler type were on trial. The average cost of ploughing over three seasons (1936-39) worked out to Rs. 2-3-8 per acre for the Hanomag tractor, while for the McCormic Deering tractor the cost per acre was Rs. 1-6-9 per acre. The fuel system in the

Hanomag tractor is not satisfactory. The engine has the tendency to stop suddenly and does not start until the fuel nozzle is either repaired or changed. Piston rings also require to be changed oftener than usual.

Manurial and rotation experiments.—The results of the permanent manurial and rotation experiments carried out at Pusa from 1930 to 1938 show that maize coming after peas was superior to that after barley, wheat or pigeon-pea. The yields of maize show that manuring with farmyard manure at 4,000 lb. per acre + 20 lb. N as rape cake was superior to other treatments. For *rabi* crops, the yield was more from 8,000 lb. farmyard manure, and 4,000 lb. farmyard manure + 20 lb. N as rape cake was at the most equal to 4,000 lb. farmyard manure per acre. The application of superphosphate improved the yield to a considerable extent. In the case of pigeon-pea, the superphosphate manure plot yielded more than any of the other plots. The addition of superphosphate after green manure gave a very high outturn, more than double that of 8,000 lb. of farmyard manure. The residual effect on maize was also considerable in this case. The yield was as high as that of 8,000 lb. farmyard manure plots.

Statistical investigations.—An examination of all the experiments conducted at Pusa clearly show that Latin square lay-outs are superior to randomized blocks.

The uniformity trial with wheat Pusa 114 carried out at Karnal for the determination of the size and shape of plots for wheat experiments was analysed. The results show that plot sizes lying between 150 sq. ft. and 500 sq. ft. have the least value of co-efficient of variation. A further increase in area did not result in any substantial reduction in the value of coefficient of variation. As regards shape of plots, rectangles having the ratio of their length to breadth lying somewhere between three and five, and blocks running counter to the length of plots appeared to be the best for experimental purposes.

At Karnal a sampling experiment on sugarcane was carried out for determining (i) the percentage attack by insects and (ii) the loss in weight caused by insects. The first method of sampling consisted in selecting from every replication a certain length of cane from rows taken at random so as to give about 100 canes. The other method was by taking about 100 canes from every replication from clumps chosen at random from the whole plot. The difference in the two methods is that in one case the sampling was confined to canes from a part of the row selected at random, while in the other clumps were selected from the whole plot. After analysing the data, it was found that the means and variances are practically the same for both the methods. In almost all cases the differences between the means and variances of the two methods can be accounted for by errors due to sampling. Hence it is found that both the methods of sampling are equally effective; the second one appears to be more convenient from the practical point of view.

Supply of seed of improved varieties of crops.—The following quantities of seed were distributed during the year :—

Variety	Quantity in pounds
Wheat (P. 12, P. 165)	40,643
Oats (B. S. 1)	12,321
Gram (T. 25)	1,151
Berseem	47
Sugarcane setts	39,350
Flax (J. W. S.)	4,115

(b) Animal Husbandry

The Sahiwal herd consisted, on 30th June 1939, of ten breeding bulls, 68 cows, 48 young male stock and 69 heifers—a total of 195 head. The vicissitudes through which the herd had to pass during the year under report, *viz.*, the shortage of green fodder following a prolonged drought during the months of October and November and the outbreak in December of foot-and-mouth disease, combined to bring about a small set-back in the average milk yield per cow per day which worked out at 21·2 lb. as compared with 22·2 lb. in the previous year. It was, however, still higher by 0·5 lb. than in 1936-37, and the general condition of the herd continued to be excellent in every respect. At the Second All-India Cattle Show held at New Delhi in February 1939, eleven out of 22 exhibited animals secured prizes and places. One of our proved early maturity bulls, Lakhan, had the unique distinction of winning the Champion Cup for the best milch bull in the Show and also the first prize for the best bull in the Sahiwal class and second place for the best bull in the Show.

Special methods of handling, feeding and general management found so successful with the Sahiwal herd are in practice since March 1936 at the Karnal Sub-Station with the Thar-Parkar herd, which is now the practical expression of the soundness of these methods. The milk yield per cow per day averaged at Karnal 19·2 lb. during the year under report as against 13·3 lb. in 1934-35.

The demand for pedigree cattle continues to be as high as ever, and is far in excess of what can be met from New Delhi and Karnal. Fifty-two head of Sahiwal cattle and 89 Thar-Parkar cattle of all denominations were sold during the year under report. The outstanding transaction was the sale of the proved bull Cholmondely to the Government of the United Provinces for Rs. 2,700 which is the record price for an Indian pedigree stud bull. The bull Narayan presented by His Excellency the Viceroy to the Afghan Government also came from the Sahiwal herd of this Institute.

Early maturity experiments.—Early maturity cows, *i.e.*, cows which were first served when only 19 to 21 months old, continue to maintain their high level of health and condition for high production. The percentage of first calvers yielding below 400 gallons is now quite insignificant, and their milk yield during the year under report averaged 18·2 lb. per head per day as against 17·8 lb. last year. A heifer born on 13th January 1936 had, under the Pusa method, presented a calf and 5,823 lb. of milk before the close of the year under report, and was due to calve a second time when she would have ordinarily given her first calf. At Karnal, where eight early maturity heifers calved for the first time, none of the calves thrown weighed less than 44 lb., and one was as heavy as 54 lb. at birth. Only one of these heifers completed her lactation by 30th June 1939, and a total of 4,257 lb. was recorded in 303 days. There are no indications that early maturity progeny are inferior to the ordinary animals either in appearance or in stamina or in milk yield. In fact, we have now reached at Delhi a standard in which we have age, weight and constitution all properly balanced and the heifers giving increasing yields without showing any signs of strain.

2. PLANT BREEDING

The production of new and high yielding varieties of crops by selection and hybridisation was continued. While continuing this line of work from

which economic results of considerable value have been obtained, attention was paid during the year to the breeding of varieties of crops which would resist disease and drought, and to the study of the inheritance of characters. The progress of work in these directions is reviewed under two headings—sugarcane breeding for which there is a special station at Coimbatore and breeding of other crops which are handled at Delhi and the substations.

(a) *Sugarcane*

Breeding work on canes which, for climatic reasons, is done at Coimbatore (Madras) to meet the requirements of both tropical and sub-tropical areas, continues to yield types which are general improvements on existing standards. Very promising results have been obtained by suitable combinations of the thick and medium Co. types available at the station. Co. 419 and Co. 421—two seedlings rapidly getting into cultivation—again proved their utility in the breeding of further improved types. Some of the new productions, when grown on a field scale, are proving superior to the earlier Co. canes in adapting themselves to conditions peculiar to certain tracts in India as well as in foreign countries. Special mention may be made of Co. 396 as an early cane in the Punjab, of Co. 421 as a heavy yielder in the North Indian sugar belt and Co. 356 (sugarcane $\times$ sorghum hybrid) as a promising medium early cane in Bihar. Co. 419 is maintaining its reputation in tropical India and Co. 432 is showing resistance to salinity in parts of Bengal. Coimbatore canes have now taken a definite place in the varietal trials of most sub-tropical regions outside India.

The sugarcane-bamboo cross, previously reported, is proving of great scientific interest and its scientific and economic possibilities are being exploited. One of the hybrids when crossed with a sugarcane $\times$ sorghum hybrid resulted in trigeneric hybrids, and about 5,000 of these are now under a full year test. A study of the F_2 generation indicates that heavy stooling and straight erect canes are two of the characters that sugarcane-breeding might ultimately gain from this venture. Intergeneric hybrids between *S. officinarum* and *Sorghum halepense*, a weed with extensive underground branching, repeatedly back-crossed with the latter, have yielded a few types of possible use as fodder.

The important point in sugarcane-breeding for economic results is the range of variation in the plant population. Once the required type is secured, it keeps true during its subsequent growth by vegetative propagation. The many hybrids produced with P.O. J. 213 as the mother, have not so far shown any evidence of segregation or of types similar to either of the parents of P. O. J. 213 itself. Crossing with the bamboo, however, showed in the F_2 generation types similar to the parents of P. O. J. 213 and in addition others unknown in interspecific hybrids of *Saccharum*. This is of considerable botanical interest. Such characters as increased growth vigour, heavy tillering, erect cane and longer life-cycle may prove to be of considerable importance in securing types of economic value.

The external and internal morphological characters of the sugarcane $\times$ bamboo hybrids were worked out during the year, and valuable results bearing on the inheritance of anatomical characters—a somewhat recent development in inheritance studies—were obtained. Cyto-genetic investigations are showing that the complex nature of inheritance in sugarcane is the result of their

chromosomal constitution. The polyploid nature of most sugarcanes and the irregularities in meiosis are rendering these investigations somewhat time-consuming. Photo-periodism experiments for overcoming the disparity in times of flowering of parents (desired to cross with each other) have given useful indications both about quantity in hour-lengths of the light and the stage of growth at which to treat the plants.

(b) *Improved varieties of crops other than sugarcane*

Wheat.—The search for wheats superior in certain characters either over the earlier Pusa selections, 4, 12 and 52, or the more recently introduced Types 111, 114, 120 and 165 was continued. In preliminary yield tests with non-shedding selections from Pusa 114 and Pusa 120, one of the selections from Pusa 120 has out-yielded the latter by about 200 lb. per acre in bulk plots.

The work on the breeding of rust-resistant wheats was continued at Simla in co-operation with Dr. K. C. Mehta. In the F_4 populations derived from nine crosses 2,640 seedlings were tested and 1,702 proved to be resistant. Selections were made for growing F_5 generation on the basis of rust resistance and other desirable characters. The F_1 populations of seven crosses were tested for reaction to black rust and in all cases susceptibility was found to be dominant. A promising degree of resistance to black rust has been noticed in some *vulgare* varieties imported from Kenya for providing breeding material. Excellent progress is recorded in the selection of wheat varieties to smuts. Of the six varieties found last year to be resistant to loose smut, five have continued so, while selections made last year in varieties showing 0.4, 9.7 and 20.1 per cent susceptibility all proved resistant. Of the forty-eight additional varieties, fourteen showed no infection this year, and two showed less than 10 per cent infection. Sixteen varieties of wheat showed a very high degree of resistance to flag smut. A start has been made with experiments to compare the relative drought-resisting capacities of the Pusa wheat types.

Oats.—Selection of oats resistant to covered smut is in progress; four of the five types found resistant last year continued so under the most vigorous infectious conditions, and one additional type has shown freedom from infection.

Rice.—A study of the inheritance of a peculiar type of variegation, involving the combination of both bi-parental and maternal inheritance, is being carried on in rice.

Oil-seeds.—Single plants with a high degree of rust resistance have been made from F_5 cultures of crosses between susceptible indigenous and resistant exotic types of linseed. In crosses between wild and cultivated species of safflower, the spiny nature of the wild species and its grey seed colour have been found to be dominant to spinelessness and white seed colour of the cultivated type. Work on the oleiferous Brassicæ has been extended to include cytological investigations. In a study of the genetics of self-sterility, two chromosomal and three genic mutations have been discovered, occurring spontaneously.

Legumes and pulses.—A wilt-resistant strain of pigeon-pea has been isolated from Pusa Type 69. The breeding behaviour of two gram mutants, viz., the tiny-leaved and the simple-leaved, was studied in selfed and crossed progenies. While the data obtained with the former mutant have shown it

to be a simple recessive, those obtained with the latter are more complicated, indicating a frequent reversibility of the mutant character in the course of breeding. A number of polyploids were obtained in gram Type 20 by the use of colchicine and studied cytologically.

Fibre crops.—Breeding work in connection with the evolution of early maturing strains of *Hibiscus cannabinus* was continued, and single plants with early maturity and other desirable characters were selected from hybrid progenies.

Potatoes.—Potato in India is subject to numerous diseases of the plant while growing in the field and of tubers in storage. The major problem in potato improvement is to breed disease-resistant varieties. The work on this crop was continued both at Delhi and Simla, and attention was chiefly paid to the breeding of disease-resistant types. Single plants resistant to Late Blight were selected from progenies of crosses involving *S. demissum* and *S. antipovicii* as the resistant parent. Work was continued also in the crosses between *S. andigenum* $\times$ *tuberosum* varieties. Among a large collection of Indian varieties, over 300 samples were studied and classified into groups after elimination of synonym stocks. Experiments in connection with the shortening of the rest period of potato were continued.

Tobacco.—The flue curing of cigarette tobacco and the experiments to see the effect of chemical fertilizers and the rotation of crops on the quality of cured leaf are in progress at Guntur. With a view to produce strains uniting high-yielding capacity with high nicotine content, the available types of *Nicotiana rustica* are studied and crosses between suitable types made. The cytology of the two interspecific hybrids, viz., *N. tabacum* $\times$ *N. plumbaginifolia* and *N. glauca* $\times$ *N. plumbaginifolia* is under study, and experiments to introduce chromosome doubling in them by colchicine have been taken in hand.

Chillies.—The genetics of a variegated chilli plant occurring in one of the cultures are being investigated. The treatment of chilli seeds with colchicine has yielded a number of polyploids for a cytological study.

3. SOILS

The programme of soil studies is a comprehensive one spread over a number of years. It is designed for the proper appreciation and consideration of the significance and practical value of the recent advances in soil science, in relation to land utilization, soil erosion, reclamation of *usar* soils, soil management and fertiliser practice, and generally to improvement in the productivity of soils under the geoclimatic, geobiological and agrobiological conditions that obtain in India. Most of the soil and crop problems must necessarily be dependent on local conditions and are, therefore, best studied locally. But the comparative study of the phenomenal characteristics of soil types in themselves and in relation to plant growth will enable us to understand many of the reactions characteristic of soil and plant processes, and give clues in regard to the extent to which the more recent developments in the knowledge of soils can add to the existing agricultural practices either in the way of enunciating new principles or modifications of the old ones. The soil work during the year was a continuation of that of the previous year and consisted mainly of the preparation of soil maps and soil studies.

Soil map of India.—Pending the completion of the projected soil studies the preparation of maps exhibiting important soil characteristics had to wait. A map showing the important soil types which was prepared in the previous year, was further scrutinised and corrected and blue prints were made for circulation to soil workers in the provinces for any additions and alterations.

Soil studies.—The comparative studies on the development and behaviour of soils under different conditions of geology and climate, were continued during the year under report. The last year's work provided further data which show that although soils derived from different rock formations, reflect to a certain extent the composition of the original rocks from which they are derived, the final result of weathering and soil formation are considerably influenced by the climatic complex and particularly by the amount and the distribution of rainfall. It should, however, be mentioned here that in assessing the relationship between soil processes and the climatic complex neither Lang's rain factor nor Meyer's "N-S quotient" is adequate. A new and additional factor, the "degree of wetness," was under investigation.

The analyses of the clay fractions of the soil were not completed, but the work done during the year and the results therefrom permit grouping of soils on a climatic basis showing that climate as predominant function assumes a particular significance in the formation and utilisation of soils. The data so far available on the analyses of clay show that under arid, semi-arid, humid and per-humid conditions, the nature of soil processes was similar in the different layers down to a depth of five feet, thus indicating the advanced age of the soils of this country. This perhaps explains the phenomenal response of Delhi soils to cropping in spite of the removal of the surface soil down to depths ranging from one to four feet.

The results on the base exchange capacity of soils do not indicate positive correlation between base exchange capacity and clay content. The black soils contain the largest amount of clay, but the latter do not appear to possess proportionately high base exchange capacity, due presumably to secondary reactions under the influence of the prevailing climatic factors.

If the analytical values of clays for their alkaline and alkaline earthy metals are plotted against the ratio of rainfall to temperature, the absorption of soda, potash and lime is evident under a low rainfall of 8.5 inches per annum, and owing to the chemical stability of the clay complex and moisture deficiency, magnesium silicates have been left comparatively unacted upon. With 50 to 60 inches of rainfall aided by the high prevailing temperature, conditions would be favourable for dissociation and for the formation of hydrogen clay which reacting with the soluble electrolytes present, forms absorption systems. With greater precipitation coupled with heat and drying, all the cations except magnesium move out, the calcium moving most quickly and easily. This is followed by the entry of the magnesium into the lattice structure and in an adsorbed state.

As data accumulated on the inherent soil characteristics which are traceable directly to the parent material and to the influence of climatic complex, a beginning was made in the study of the relationship to cultural operations and crop growth.

Nitrogen transformation in soils.—The investigations during the year provided further evidence that the effect of sunlight on the nitrification process

was one of a decided check. When all the different forms of nitrogen in the course of nitrification in the soil were totalled up, there was always some shortage in the total nitrogen. That this was due to the loss of elemental nitrogen was established by gasometric tests. The loss in the laboratory (not exposed to sunlight) estimations amounted to about eight per cent of the combined nitrogen added to the soil.

4. FERTILISERS, MANURES AND PLANT NUTRITION

The combined rotational and manurial experiments were continued at Pusa. With the harvest of the year under report the results of eight years' experiments are available. In unmanured plots the yield of maize after a crop of peas was nearly twice the yield of maize following a crop of pigeon-pea (*Cajanus indicus*), the yields being 744 pounds and 444 pounds respectively. Maize after wheat yielded 644 pounds. The effect of the addition of a mixture of fertilisers (20 lb. N as ammonium sulphate 40 lb. P_2O_5 as superphosphate and 25 lb. K_2O as potassium sulphate) was not equivalent to that of 4,000 lb. of farmyard manure.

The yields of wheat following maize were better than those of barley, peas or pigeon-pea after maize. An application of twenty pounds of nitrogen as ammonium sulphate had no effect on wheat following maize, but applications of either rape cake or a mixture of nitrogen and phosphate brought up the yield to the level of that obtained with 4,000 lb. of farmyard manure.

Four thousand pounds of farmyard manure gave an yield nearly double of that from an unmanured plot. Eight thousand pounds of farmyard manure did not give an yield double of that with 4,000 pounds. Forty pounds nitrogen as ammonium sulphate showed no appreciable increase in yield over the unmanured plots, but when combined with superphosphate the yields were considerably improved.

Plant nutrition—Soil conditions and manuring in relation to quantity and quality of crops.—In close association with the investigations on soils and fertilisers were the studies on plant nutrition in general and in particular the effect of soil conditions and fertilisers and manurial applications on plant metabolism and on the quality of the end products of that metabolism. Work done during the year under review provided further support to that reported in previous years by the workers at this Institute in showing that manures and fertilisers are capable of influencing the composition and quality of the crop to such an extent as to affect appreciably its value as seed and as food. A further and unexpected confirmation of this was found in the old records of the Section of the Imperial Agricultural Chemist. About twenty-five years ago Dr. Leather, the then Imperial Agricultural Chemist, studied the changes in the composition of *gangajali* wheat, and recorded that under different systems of fertiliser applications of nitrogen and phosphate he could alter the protein and starch content of the grain. The results were written up for publication by Dr. Leather himself, but before he submitted them for publication he retired from service.

The knowledge that manures and fertilisers can influence the quality of crop, is new and was originated by the workers at this Institute about ten years ago, and necessitates a change in our views on the theory and practice of manuring. The writer had shown about ten years ago by experiments with

crops and animals (1) that manures, particularly organic manures, function directly in plant nutrition in providing substances analogous to vitamins in animal nutrition, (2) that the course of plant metabolism and protein make-up vary with the nature of the soil conditions and nutritional factors available to the crop, and (3) that therefore a closer and direct connection exists between soil and plant nutrition and animal nutrition including human nutrition.

This discovery is important from the scientific and practical points of view and has opened up new fields of research. From the scientific point of view it reveals similarity in the essentials of the physiological mechanism in all life and the universal nature of the fundamental principles of nutrition for all living beings, although there may be varying degrees in the powers of accommodation and adaptability in different forms of life. From the practical point of view, the new knowledge brings into relief the interrelationship between soil, plant and animal nutrition and the necessity for research for a rational system of manuring our soils and crops to the best advantage.

These results, which were first announced about thirteen years ago, did not receive general acceptance due partly to our knowledge on the problem being inadequate and partly to the difficulties in abandoning the narrow view points resulting from a too limited experience. In the few years that have elapsed sufficient data have accumulated on the subject both from our own experiments and from those of others in different parts of the world. In order to arrive at a clear understanding of the present position and to make our views more definite in regard to manurial and fertiliser research programmes, it will be useful to make a brief survey of the more important recent developments on the subject. This the Imperial Agricultural Chemist has done and will be found in his report printed elsewhere in this volume.

Considering one important aspect of the subject, namely, food production for national nutrition, the survey brings out clearly the importance of the phenomenon of the interrelationship between the soil, plant and animal in respect to growth and development. In a country like India, where the great majority of soils are poor in organic matter and where in many cases one variety of grain forms the bulk of the diet of the bulk of the population, the necessity for improving the value of the food at its source is evident. Dietetic deficiencies can be made up by the addition of pulses, but when, as it appears, the composition and biological value is likely to be affected by manuring, fundamental investigations on the subject are necessary. All this goes to show not only the necessity for organic matter and manure in any sound system of manuring, but also to the need for research in our resources of organic manures and on the proportions of organic manures and fertilisers to be used for securing the best results.

Work on varietal differences in plant nutrition and the fixation of nitrogen by the maize plant was continued.

5. INVESTIGATIONS ON AGRICULTURAL PRODUCE AND INDUSTRIES

Sugarcane and gur investigations.—Three lines of work were in progress. One was the practical aspect in which tests were carried out on the scale and conditions that obtain with the cultivator. The second was the study of the chemical constituents of sugarcane juices and *gur* in their relation to the colour

and keeping quality of *gur*, and the third was concerned with investigations on reducing the cost of production of active carbon.

Juices clarified with activated paddy husk carbon yielded *gur* of better colour and keeping quality, and *rab* similarly prepared matured earlier and yielded by the open pan method economically higher quantities of bright and crystalline first and second sugars than those obtained by the usual methods.

A combined furnace (new type 938) for *gur* and carbon manufacture was devised. The total cost of constructing the furnace with brick and cement was Rs. 100. It will accommodate both the processes of carbon manufacture and open pan boiling in a compact space of 30 × 20 feet and provides for the better utilisation of the heat of the flue gases.

Further experiments were carried out on the reduction of the cost of active carbon manufacture. By effecting reduction in the cost of reagents, by devising means for the better utilisation of the heat of flue gases and by employing cheaper kinds of fuel, it was found possible to bring the cost of carbon production to less than one pice per pound of finished carbon, depending on the nature of the materials employed.

The active carbon process of *gur* and sugar manufacture has been steadily gaining in popularity. From large-scale trials carried out by him, the Agricultural Engineer to the Government of Bengal expressed the view that, in so far as sugar by the open pan process was concerned, the manufacture of active carbon and its use in the production of white sugar by the open pan process more than repaid its cost by the increased recovery of white sugar. In regard to *gur* he expressed the view that, compared to other methods of *gur* manufacture, the active carbon method will not be a paying proposition unless people would pay a higher price for a really good *gur*.

6. PESTS AND DISEASES OF CROPS

Pests of sugarcane.—Work on pests of sugarcane financed by the Imperial Council of Agricultural Research was developed during the year under report. Intensive studies were carried out at New Delhi and at the substations at Karnal, Pusa and Coimbatore on the seasonal incidence of borers, etc., and valuable data were obtained on the habits of the pests and their parasites. A survey of sugarcane borer populations in seventeen important regions has also been initiated. Varietal observations at Karnal and Pusa show, on statistical analysis, that the Coimbatore cane Co. 331 is the most resistant to the top-borer *Scirpophaga nivella* which appears when the plants have formed stalks and is generally active during the rest of the life of the crop. The larva of this borer having been noticed to bore first into the midrib through which it tunnels to the leaf base from whence it bores into the shoot, confirmation has been obtained of an earlier observation made in Java to the effect that the resistance of a cane to top-borer attack is correlated with the hardness of the midrib. The midrib in varieties resistant to this borer has been found, on dissection, to be harder than in those more susceptible, and the hardness seems to be due to higher silicification and lignification in the concerned plant cells.

Field operations in biological control were carried out during the year with encouraging results. Mass liberations of *Trichogramma minutum* Riley

against the stem-borer *Argyria sticticrasis* were conducted at Cuttack and Banki in Orissa and Lalseriya and Madhopore in Bihar. There is dependable evidence to show that this parasite does exercise a considerable check on the stem-borer and contributes to higher yields. Conservation of the egg parasites of *Pyrilla* spp. from stripped plots was tried at Palhera farm (Meerut District). Parasitized egg-masses collected from stripped leaves were conserved in wire-gauze cages which were distributed over the infested area. Emerging parasites escaped into the field while emerging nymphs of the host were imprisoned in the cage.

Spraying of an emulsion of one ounce of kerosene oil and one ounce of soap in a gallon of water in a crop about three feet high in Bhopal State checked the incidence of *Pyrilla* in an area of three and a half acres at a cost of Rs. 3-11-0 per acre.

Pests of cotton.—The rate of development and power of reproduction of *Earias fabia* (spotted bollworm), a destructive pest of cotton, and its most important parasite *Microbracon lefroyi* were studied at several constant temperatures ranging from 15°C. to 50°C. under different saturation deficiencies. Long continued exposures to a temperature of 13°C. or below have, in the laboratory, proved fatal to both species, contrary to the common belief that severe winters are more injurious to the parasite than to the host. At the various temperatures tried within the vital limits, the parasites developed two to two and a half times faster than the pests. It is a common observation that during years of good rain spotted bollworms are not very abundant in the field and the phenomenon is ascribed to the mechanical action of rain in shaking off attacked buds and bolls and drowning thereby the bollworms living therein. The work carried out in the laboratory indicates that it is not solely the mechanical effect of rain which is useful but that summer rains help in controlling the pest by lowering the temperature which is beneficial to the development and viability of the parasite and by raising the humidity which is injurious to the host. High temperature and low humidity during the summer have been observed to be the chief limiting factors in the multiplication of the parasite in the field. *Melcha nursei*, another parasite of great potential importance, appears to have vital limits of temperature and humidity identical with those of *Microbracon lefroyi*.

Insect vectors of tobacco leaf-curl disease.—A further year's work has shown that this disease is more widely distributed in the Indo-Gangetic plains than previously believed, and that, besides sann-hemp and *Ageratum conyzoides*, there are other alternate hosts from which the white-fly (*Bemisia gossypiperda*) can transmit the disease to tobacco and *vice versa*. These are *Zinnia elegans*, *Solanum nigrum*, *Euphorbia hirta*, *Vernonia cinerea*, *Lycopersicum esculentum*, *Launea asplenifolia*, *Sida rhombifolia* and *Sida humilis*. In fact, the white-fly has been found feeding on about seventy-five plants; the eradication of alternate host plants advocated in some other countries, is, therefore, not a practical method of control for North India. The other possible method is the protection of the crop from infestation by the white-fly. A systematic survey has shown that the bug is common and most viruliferous during the autumn (September to October). At this time the tobacco crop is either still in the nurseries or has recently been planted in the fields. Some preliminary spraying and dusting experiments have been carried out to protect the crop at this time of the year, and the results obtained are quite encouraging.

Pests of fruits and vegetables.—The lures tested last year were tried again on a very large scale against the fruit-fly *Decus ferrugineus*. It was found that 'Clensel', a proprietary insecticide, and pollard bait prepared from wheat bran (8 oz.), borax (8 oz.) and water (1 gallon) were almost equally effective in attracting the flies. The trap devised and made locally at Rs. 1-14-0 per dozen was as efficient as glass bottles supplied by Clensel Works at Rs. 6 per dozen. Experimental varieties of safflower growing at Delhi have been found attacked by a fruit-fly *Acanthiophilus helianthi*; this is the first record of the incidence of a pest of this genus in India.

Studies on Indian parasites.—The growing interest in control of insect pests by means of their natural enemies has made it necessary to have as complete a record as possible of the parasites and predators attacking various insects in the field at different times of the year in various parts of India. During the year under report, complete data available on the biology, hosts and distribution of known Indian Chalcidoidea, the most important group of parasites, were compiled and sent up for publication as a Bulletin. Systematic work on certain groups of parasites has resulted in elucidation of the taxonomy of *M. greeni*, *M. lefroyi*, *M. brevicornis* and *M. hebetor*. It has been shown that the colouration of Braconid parasites does not afford reliable diagnostic character, as the same species bred under different temperatures and humidities shows great variation in colouration.

Insecticides.—In view of the great importance of replacing imported mineral insecticides by cheap vegetable poisons easily available in the country, and incidentally less poisonous to men and live-stock, a study of indigenous insecticides was started during the year under report. A beginning has been made with species of *Tephrosia*, a genus with several species well distributed throughout India. *Tephrosia purpurea* grows commonly in Delhi and flowers practically all the year round.

Control of fly nuisance.—The Public Health Officer, New Delhi Municipality, having been impressed with the effectiveness of the methods of controlling fly nuisance on the Institute Estate, requisitioned the assistance of the Imperial Entomologist in the control of flies in the night-soil silt-beds at Kilakori Sewage Farm. As a result of some experiments it was thought that the thickness of the silt layer was an important factor in the breeding of flies and that it could safely be up to 3 inches. It is gratifying to record that in beds in which silt is being laid now in this thickness, the breeding of flies is less than in those in which silt is being put in the old fashion.

Diseases of sugarcane.—The research work carried out under the scheme for investigation of mosaic and other diseases of sugarcane, during its tenure of seven years, has given rise to the following more important findings with regard to mosaic :—(1) The loss in yield is quite small even in a heavily infected crop, but is somewhat larger in thick canes than in thin canes. (2) There is a certain amount of natural transmission of the disease to healthy plants even under North India conditions. The discovery of *Aphis maidis*, a known vector of the disease in other countries, found colonizing on sorghum indicates the possible means of transmission in India. (3) The spread of mosaic by natural means is to a large extent counteracted by the phenomenon of "recovery" which is the production of healthy canes arising from setts taken

from diseased canes—a surprising phenomenon in view of the fact that sugarcane mosaic virus, like other viruses, is systemic in nature. (4) The comparatively slow rate of natural transmission in North India would lead to the conclusion that the disease can easily be controlled by selection of setts from healthy plants. At Pusa selections were made from a crop of Co. 313 showing between 70 and 90 per cent infection. The crop raised from these selected setts showed only three per cent infection.

A careful study of a large collection of sugarcane smut from India, Burma, Java, China, the Philippines and Mauritius has shown that the disease is caused by one species and two varieties of this species. *Ustilago scitamenia* was already known to have wide distribution in India. *U. scitamenia* var. *Sacchari-Barberi* occurs in East and North India, but is absent from West and South India. The principal sugarcane smut in China and the Philippines seems to be a second variety, *U. scitamenia* var. *Sacchari officinarum* which was collected in India in 1908.

The research scheme financed by the Imperial Council of Agricultural Research has been given a further lease of life to deal with practical problems arising from a survey of diseases which will include testing of different varieties for resistance to disease.

Wilt diseases.—An interesting discovery has been made in the gram wilt disease caused by a species of *Fusarium*. The disease appears to be favoured by very high temperatures, and there are indications that late sowing of gram may bring about marked reduction in this serious disease. In plots sown at a week's interval from 23rd September to 28th October, those put down before the middle of October were poor in germination and had a larger percentage of wilted plants. Other *Fusarium* diseases to which attention has been paid during the year are wilts of pigeon-pea and sann-hemp. Apparently there is a fairly high degree of specialization, and the fungus causing wilt of pigeon-pea has been found unable to cause wilt of sann-hemp and *vice versa*. This specialization, however, does not seem to be complete, a certain amount of cross-infection taking place.

Fruit diseases.—The discovery in Orissa of a disease of bananas which shows close resemblance to the dreaded “bunchy top” disease, which has caused havoc in several banana-growing countries, emphasises the importance of more intensive study of virus diseases in India.

The survey of fruit spoilage in Delhi markets, which has now been conducted systematically for more than eighteen months, has shown that not only are the losses very great, but are far greater in fruits of Indian origin than in same fruits imported from Australia, America and Japan. A large proportion of spoilage appears to originate from damage caused to fruits prior to or during transport. A profitable field seems to have been opened up for operation of marketing organisations.

The scientific papers published during the year are listed in Appendix III (pp. 142—144).

III. GENERAL ADMINISTRATION

Staff.—Such staff changes as took place in various Sections will be found in Appendix I (pp. 137-138.).

Schemes of research financed by the Imperial Council of Agricultural Research.—All the nine schemes, the details of which were given in the report for 1936-37, continued to be in operation during the year. The following four schemes relating to sugarcane research, *viz.* (1) Diseases of Sugarcane, (2) Insect Pests of Sugarcane, (3) Genetics of Sugarcane and (4) Sugarcane Substation, Karnal, the terms of which expired during the year, were each extended for a further period of three years. Besides, the Imperial Council of Agricultural Research made a grant of Rs. 300 for analysis of soils collected in connection with the Cinchona Inquiry.

Training.—There were 59 candidates for admission to the post-graduate courses beginning in November 1938, of whom 40 were recommended by the Provincial authorities. Nineteen applicants were selected for admission: six in Botany, four in Agricultural Chemistry, three in Entomology, one in Mycology and five in General Agriculture. Of these, one in Entomology left the course on getting an appointment. Ten students completed the course during the year and were awarded the Institute Diploma: three in Botany, one in sugarcane Breeding, four in Agricultural Chemistry, one in Entomology and one in Mycology. The one-year course in Farm Organization and General Farm Engineering was completed by five students.

Admissions for post-graduate training at this Institute were in the past from 1st November every year, but experience has shown that 1st October will be a more suitable date for the beginning of a new session as it represents the start of the *rabi* season and is thus important from the point of view of agricultural training. The Council of the Institute has therefore decided, after consulting the Directors of Agriculture in provinces and States, to change the date of admission to 1st October from the year 1939.

Besides the regular post-graduate courses, facilities were afforded to 9 students deputed by provinces and universities for short training in special subjects: three in sugarcane and soil analysis, one in plant-breeding technique, one in plant pathological technique, one in principles of applied entomology, and three in milking and handling of cows and calf-rearing. Seven post-graduate students and 22 I. D. D. students of the Imperial Dairy Institute, Bangalore, were afforded facilities to study the methods of cattle-breeding and mixed farming at the Agricultural Substation, Karnal. The post-graduate students spent a short period at the Institute at New Delhi as well. A few officers of the Gur Development Scheme of the United Provinces were given facilities to study the process of the manufacture of active carbon and its application in *gur* and sugar manufacture.

Eleven honorary research workers were admitted for carrying out a definite piece of work—five in Chemistry, one in Mycology, three in Entomology and two at the Sugarcane Breeding Station at Coimbatore.

For further details attention is invited to Appendix II (pp.139—141).

Library.—The total number of publications received in the Library both by way of exchange and by purchase was 3,345. Over 2,700 books were issued on loan, of which 396 were sent out to the scientific workers in the provinces and universities.

IV. ACCOUNTS

The total expenditure of the Institute and its Sub-stations at Karnal and Coimbatore during the financial year ended March 1939 amounted to Rs. 7,41,848.

Name of establishment	Expenditure Rs.
General expenditure of the Institute, including the Office of the Director, Irrigation, Power Supply, Gas Plant and the Estate Establishment	2,19,365
Agricultural Section	1,39,037
Botanical Section	46,752
Chemical Section	75,657
Entomological Section	66,925
Mycological Section	41,388
Agricultural Sub-station, Karnal	68,513
Sugarcane Sub-station, Coimbatore	84,211
	7,41,848

The expenditure of the various research schemes financed by the Imperial Council of Agricultural Research amounted to Rs. 1,48,476, as shewn below, which was met from the funds provided by the Imperial Council of Agricultural Research.

	Rs.
(a) Research on Mosaic and other Diseases of Sugarcane .	19,742
(b) Research on Insect Pests of Sugarcane	27,420
(c) Research on Chemistry of Sugarcane	6,062
(d) Scheme for analysis of Cinchona Soils	286
(e) Scheme of Pedigree Herd Book—Sahiwal Breed .	2
(f) Research on Genetics of Sugarcane, Coimbatore .	7,280
(g) Sugarcane Sub-station, Karnal	13,549
(h) Tobacco Breeding Sub-station, Guntur	23,018
(i) Potato and Wheat Breeding Sub-station, Simla—	
Potato Breeding	19,653
Wheat Breeding	6,829
	26,482
(j) Botanical Sub-station, Pusa	24,635
Total .	1,48,476

The receipts of the Institute and its Sub-stations amounted to :—

	Rs.
Main Institute	35,900
Agricultural Sub-station, Karnal	36,575
Sugarcane Station, Coimbatore	9,033

REPORT OF THE IMPERIAL AGRICULTURIST

(ARJAN SINGH, ASSISTANT AGRICULTURIST)

1. Agricultural Section New Delhi

I.—GENERAL FARMING

1. SOIL FERTILITY

Another block of 20·56 acres was reclaimed in the paddock Nos. 1 and 2 and added to the arable area of the farm. The net area available for cultivation during the year under report was as follows :—

	Acres
Shadipur Block	22·43
Main Block	240·00
Middle Block	43·89
Sewage Block	23·45
Top Block	50·56
Paddock Area	20·56
Total	400·89

Except the sewage area, in which effluent of the activated sludge plant is utilised, the whole area is controlled by irrigation water supplied by the Central Public Works Department.

The Main Block, Top Block, Paddock Area and Sewage Block are worked on a mixed farming system for the production of food and fodder for the live-stock, while Shadipur Block and Middle Block have been set aside for permanent and long-term experiments. Seasonal experiments will also be accommodated in the Main Block according to the rotation of crops grown on it.

As already stated in the previous report, the land had been severely dealt with for levelling, and as a consequence, the entire area has been put under a definite rotation and manurial treatment to bring it to a level of uniformity.

The following rotations are followed on the farm :—

Rotation No. 1

<i>Kharif</i>	<i>Rabi</i>
1st year... Leguminous pulses such as <i>guara</i> (<i>Cyamopsis</i> sp, cowpeas and <i>meth</i> (<i>Phaseolus</i> sp.).	Oats
2nd year... <i>Jowar</i> (<i>Sorghum</i> sp.) for green fodder and silage	Fallow
3rd year... Cowpeas, <i>meth</i> , <i>guara</i> , soybean, sann-hemp, etc., for or seed	Gram
4th year... Green manure.	Oats

One-fourth area (about 45 acres) under the rotation will receive farmyard manure every year at 300 maunds per acre (1 maund=82·3 lb.).

Rotation No. 2

<i>Kharif</i>	<i>Rabi</i>
1st year... <i>Jowar</i>	Gram
2nd year... Fallow	Gram

Rotation No. 3.

<i>Kharif</i>	<i>Rabi</i>
1st year... Early <i>jowar</i>	Berseem
2nd year... Pulses for grazing	Green fodder

Rotation No. 4

<i>Kharif</i>										<i>Rabi</i>
1st year...	Cotton	.	.	.	.	.	.	.	.	Cotton.
2nd year...	Fallow	.	.	.	.	.	.	.	.	Barley.

Rotation No. 5

<i>Kharif</i>										<i>Rabi</i>
1st year...	Jowar	.	.	.	.	.	.	.	.	Gram
2nd year...	Green manure	.	.	.	.	.	.	.	.	Wheat
3rd year...	Fallow	.	.	.	.	.	.	.	.	Wheat

Rotation No. 6

<i>Kharif</i>										<i>Rabi</i>
1st year...	Maize	.	.	.	.	.	.	.	.	Peas
2nd year...	Cotton	.	.	.	.	.	.	.	.	Cotton
3rd year...	Sugarcane	.	.	.	.	.	.	.	.	Sugarcane
4th year...	Fallow	.	.	.	.	.	.	.	.	Wheat

Sugarcane and maize will receive farmyard manure at 10 tons per acre.

Rotation No. 7

<i>Kharif</i>										<i>Rabi</i>
1st year...	Green manure	.	.	.	.	.	.	.	.	Fallow
2nd year...	Sugarcane	.	.	.	.	.	.	.	.	Sugarcane
3rd year...	Fallow	.	.	.	.	.	.	.	.	Gram

Sugarcane is to be manured with farmyard manure at 300 maunds per acre.

Rotation No. 8

<i>Kharif</i>										<i>Rabi</i>
1st year...	<i>Bajra</i> (<i>Pennisetum</i> sp.) and cowpeas	.	.	.	.	.	.	.	.	<i>Bajra</i> & cowpeas
2nd year...	Fallow	.	.	.	.	.	.	.	.	Barley

Rotation No. 9

<i>Kharif</i>										<i>Rabi</i>
1st year...	Maize	.	.	.	.	.	.	.	.	Peas
2nd year...	<i>Bajra</i> & cowpeas	.	.	.	.	.	.	.	.	<i>Bajra</i> & cowpeas
3rd year...	Groundnut	.	.	.	.	.	.	.	.	Groundnut
4th year...	Fallow	.	.	.	.	.	.	.	.	Wheat

Maize and *bajra* will receive farmyard manure at 10 tons per acre.

It will be seen from the above rotations that ample provision has been made for the increase or maintenance of fertility of the soil by fallowing, green-manuring, growing of leguminous crops in rotation and application of organic manures,

The above rotations were in the first year of the first round, and the effect of these on the soil fertility will only be seen in the second round.

2. MANURING

Great attention was paid to the collection and preservation of all sorts of weeds and waste organic matter from the land and also of cattle-dung from cattle byres and paddocks and storing them in manure pits.

During the year, 13,094 maunds of farmyard manure was made and used for manuring 43·5 acres of land at 300 maunds per acre. The compost made last year was ready for use and has been included in a manurial experiment along with farmyard manure and activated sludge.

3. SEASON AND CROPS

Season.—The total rainfall during the year from June 1938 to May 1939 amounted to 10·38 inches as compared with 20·30 inches in the previous year.

The monsoon was very late and broke on the 16th July. An appreciable amount of rain was recorded on 16th, 17th, 19th, 30th July and 19th August 1938 and also on 17th February 1939; otherwise, dry and drought conditions prevailed throughout the season. All the *kharif* and *rabi* crops, except pulses and gram, were sown after irrigation.

Crops.—The statement given below shows the yields of crops grown on the farm during the year under report.

Statement of crop yields during 1938-39

Name of block	Plot No.	Crop & variety	Area in acres	Yield in maunds*		Average yield per acre during 1937-38 (Mds.)
				Total	Average per acre	
Main Block	4	<i>Jowar</i> —green fodder.	15·00	4470·13	298·01	
	5	„	10·00	1959·00	195·90	
	6	„	14·86	5204·90	350·26	
	13	„	15·00	1674·50	111·63	
	14	„	6·25	2794·78	447·16	
Shadipur Block	A	„	1·50	524·50	349·67	
	B	„	3·90	308·00	78·97	
	C	„	2·02	197·00	97·53	
Top Block	..	„	27·32	9092·03	332·80	
Middle Block	C	„	1·50	252·15	168·10	
Sewage Block	..	„	10·58	2932·45	277·17	
Main Block	14	<i>Jowar</i> —seed	8·60	Average	272·49	170·53
				11·25	1·31	

* 1 maund=82·3 lb.

Name of block	Plot No.	Crop & variety	Area in acres	Yield in manuds*		Average yield per acre during 1937-38 (Mds.)
				Total	Average per acre	
Sewage Block . . .	..	Jowar—seed .	5.31	17.40	3.28	
				Average	2.06	..
Shadipur Block . .	A	Maize No. 2 .	0.50	4.65	9.30	
	C	„ .	0.50	3.33	6.66	
Middle Block . .	C	„ .	0.50	3.35	6.70	
				Average	7.55	5.63
Main Block . .	A	Maize No. 3 .	1.00	6.68	6.68	5.80
	5	Maize No. 1 .	3.00	33.23	11.08	4.64
Sewage Block . . .	..	Soybean—Coorg .	0.20	0.50	2.50	
		„ Chocolate .	0.33	1.00	3.03	
		„ Black .	0.33	1.21	3.67	
		„ Yellow .	0.33	1.30	3.94	
				Average	3.37	..
Middle Block . .	C	Bajra & Cowpeas	1.00	9.31	9.31	..
Middle Block . .	A	Arhar—Local .	0.27	6.03	22.33	
	A	„ Pusa T. 41 .	0.45	5.75	12.78	
	A	„ Pusa T. 51 .	0.45	6.78	15.07	
				Average	15.86	..
Shadipur Block . .	C	Groundnut .	0.50	2.13	4.26	
Shadipur Block . .	A, B & C	Cotton 4F .	0.666	4.34	6.52	
		„ 289F .	0.666	3.09	4.64	
		„ M. 60 A/2 .	0.666	3.46	5.20	
				Average	5.45	..
Main Block . .	1	Oats B. S. 1 .	15.00	410.15	27.34	
	2	„ .	15.00	436.07	29.07	
	3	„ .	14.75	409.93	27.79	
	10	„ .	14.50	433.45	29.89	
	11	„ .	15.00	480.00	32.00	
	12	„ .	14.11	432.70	30.67	
Middle Block . .	B	„ .	15.00	372.85	24.86	
				Average	28.78	27.19
	C	Oats—hybrids .	4.83	137.00	28.37	..
Shadipur Block . .	A4	Wheat P. 125 .	0.50	19.73	39.46	
	A8	„ .	1.50	46.81	31.21	
	A9	„ .	1.50	35.75	23.83	
	B8	„ .	1.50	37.50	25.00	
	B9	„ .	1.50	33.86	22.57	
	C4	„ .	0.50	15.97	31.94	
Middle Block . .	C8	„ .	1.50	44.22	29.48	
	C9	„ .	1.50	40.95	27.30	
				Average	27.48	..
	C4	Wheat P. 165 .	0.50	12.09	24.18	
	C	„ .	0.56	9.04	16.14	
	A	„ .	1.10	19.68	17.89	
				Average	18.89	16.73
	A	Wheat P. 114 .	1.00	18.79	18.79	14.43

* 1 maund=82.3 lb.

Yield in maunds*

Name of block	Plot No.	Crop & variety	Area in acres	Total	Average per acre	Average yield per acre during 1937-38 (Mds.)
Sewage Block . . .	..	Barley—Pusa T. 13	5.54	252.83	45.64	
Shadipur Block . . .	A	„ . .	0.50	20.60	41.20	
	B	„ . .	0.50	13.15	26.30	
Middle Block . . .	C	„ . .	0.50	16.25	32.50	
				Average	43.02	29.51 (local)
Shadipur Block . . .	A	Gram—Pusa T. 25 .	1.50	11.45	7.63	
	B	„ . .	1.50	20.25	13.50	
				Average	10.57	11.53
Shadipur Block . . .	A	Peas— <i>Kerao</i>	0.50	8.13	16.26	
	C	„ . .	0.50	7.45	14.90	
Middle Block . . .	C	„ . .	0.50	8.38	16.76	
				Average	15.97	15.00
	C	Peas—Pusa S. 29 .	1.50	7.63	5.09	
Sewage Block . . .	..	„ . .	1.68	46.60	27.74	
				Average	17.05	
Top Block . . .	1, 2, 3, 5 & 6	Berseem—green fodder.	30.09	11946.99†	397.04	485.75
Roadside plot . . .	..	Lucerne—green fodder.	0.75	216.00‡	288.00	..
Shadipur Block . . .	A	Sugarcane Co. 313	0.50	180.13	360.26	
Middle Block . . .	A	„ Miscel-laneous varieties.	2.50	597.63	239.05	
				Average	259.25	364.55

From the above statement, comparing the yields with the last year's averages, it is evident that the yields have considerably improved inspite of the dry and drought conditions which prevailed throughout the year.

Jowar—Out of the total area of 121.84 acres under this crop, 107.93 acres were cut for green fodder and silage with an outturn of 272.49 maunds per acre as compared with 170.53 maunds per acre last year. The remaining crop on 13.91 acres was kept for seed. There being no crop in the neighbourhood, the seed crop was badly damaged by birds, inspite of all precautions taken for scaring them away, and consequently a very little outturn was obtained. *Jowar* has proved to be one of the best fodders, and cattle relish it both as green fodder and silage.

Maize—The three Pusa selections, viz., Nos. 1, 2 and 3 are getting gradually acclimatized. As will be seen from the statement, the yield of corn from these varieties was more than that of last year. Its growth for green fodder has not shown much promise during the last two years.

Pulses—These were sown on the break of monsoon on 45 acres in the Main Block as usual, but the crop was totally wiped out by the hairy caterpillar pest in its young stage.

Arhar—Three varieties of *arhar* (pigeon-pea), viz., Pusa 41, Pusa 51 and local were tried for the first time on single plots. The growth was satisfac-

†4 cuts.

* 1 maund = 82.3 lb.

‡6 cuts.

tory, and as there was no frost, the yield was fairly good. The local variety gave the highest outturn, *i.e.*, 22·33 maunds per acre.

Cotton—Three varieties of cotton, *viz.*, 4 F, 289 F and M. 60 A/2, were grown in four different places on the farm on 1/6 acre plots under each variety. All the three varieties had too much of vegetative growth and consequently the yield of *kapas* (seed-cotton) was not very high. As will be seen from the statement of yields, 4 F is better than the other two varieties. M. 60 A/2 is an early variety.

Oats—An area of 103·36 acres was sown under oats B. S. 1 from which 2975·5 maunds of grain was obtained—an average yield of 28·78 maunds per acre. Oats B. S. 2, Hybrid G, Hybrid C, Hybrid J and Hybrid VII-578 were also grown on an area of 4·83 acres, the yields of which were as follows :—

Variety	Area	Total yield (Mds.)	Average yield per acre
	Acre		
B. S. 2	1·04	31·65	30·43
Hybrid G	1·00	29·68	29·68
„ C	1·11	33·10	29·82
„ J	1·06	27·18	25·64
„ VII-578	0·62	15·40	24·84

Thus the total outturn from an area of 108·19 acres was 3112·15 maunds — an average of 28·77 maunds per acre as against 27·19 maunds per acre last year.

Wheat—The outturn of wheat was also better this time as compared with the last year's yield. Pusa 125 was grown for the first time on an area of 10 acres from which an average yield of 27·48 maunds per acre was obtained. The outturns of Pusa 165 and Pusa 114 were 18·89 maunds and 18·79 maunds per acre, respectively, in comparison with 16·73 maunds and 14·83 maunds per acre last year.

Barley—The local variety which was grown last year was discarded as it was badly affected with smut. Pusa type 13 was grown instead on four different plots. The average yield was 43·02 maunds per acre as compared with 29·51 maunds last year. The crop was absolutely free from smut and other diseases.

Gram—Seventy-six acres were sown unirrigated in the Main Block, and due to the failure of rains and shortage of irrigation, the harvest was not a success.

Berseem—The newly levelled area in the Top Block was put under berseem immediately after a heavy crop of *jowar* was harvested. The seed was sown in the first week of October as usual, but the soil having undergone severe levelling and exhaustion by *jowar*, the first cut of berseem, which becomes ready in the beginning of December under normal conditions, was not ready till the middle of January, and the outturn was very poor. After the first cut, the crop began to show good progress and the subsequent cuttings were normal, and green fodder was available up to the end of May 1939.

The total area under berseem was 30·09 acres against 44·75 acres last year. This gave sufficient green fodder, but nothing was available for hay.

The average yield of green fodder was 397·04 maunds per acre as against 488·75 maunds last year. The condition of the crop was exactly the same at the Agricultural Sub-station, Karnal, but that was due to the late sowing (middle of November) of the crop on account of late opening of the canal.

As regards seed production, no difficulty was experienced, and seed setting was excellent both at Delhi and Karnal, but the early monsoon did considerable damage to the seed crop while the seed was in the process of ripening. At Karnal, a portion alone of the crop could be threshed before rains and this gave about 10 maunds first quality seed having no red seeds. The seed from the rest of the crop, which after harvesting had to be stored in sheds, was not satisfactory, a great proportion became red and dead. The same was the case at Delhi. The question of early monsoon is, therefore, of great importance when dealing with the seed crop of berseem.

Lucerne—Lucerne was sown on a 3/4 acre plot along the road-side area in October 1938. It produced green fodder, cut once a month, and the yield was 288 maunds per acre up to end of June 1939. The crop, unlike berseem which dies after June, is still growing.

Grasses—The planting materials of Elephant-grass, Guinea-grass, Rhodes grass and Sudan-grass were multiplied during the year. Out of these, Elephant-grass, which was planted in February 1939 and cut in June 1939, gave an outturn of 407·38 maunds from 0·89 acre plot in the first cut. It was chopped and fed to milch cows, but they did not relish it as the fodder is a bit coarse for them. The work cattle consumed it without any difficulty.

Sugarcane—Sixty-one Co. sugarcane varieties were planted on the farm for multiplication of the planting material along with the following 23 Co. sugarcane varieties which were received for trial from Coimbatore during the year 1938 :—

Co. 446, Co. 447, Co. 448, Co. 449, Co. 450, Co. 451, Co. 452, Co. 453, Co. 454, Co. 455, Co. 456, Co. 534, Co. 535, Co. 536, Co. 537, Co. 538, Co. 539, Co. 540, Co. 541, Co. 542, Co. 543, Co. 544 and Co. 545.

Of the above 23 varieties obtained from Coimbatore, three varieties, viz., Co. 451, Co. 454, Co. 456, failed absolutely and did not flourish. Of the remaining 20 varieties, Co. 537 showed much promise, while Co. 450, Co. 535, Co. 536, Co. 538, Co. 539, Co. 543 and Co. 545 did fairly well, and Co. 446, Co. 447, Co. 448, Co. 449, Co. 452, Co. 453, Co. 534, Co. 540, Co. 541, Co. 542 and Co. 544 made a poor show.

Out of the 61 old Co. sugarcane varieties planted on the farm in March 1938 for multiplication, the following varieties have shown the best sucrose content during the months of January and March 1939 : Co. 374, Co. 378, Co. 434, Co. 500, Co. 501, Co. 503, Co. 506, Co. 508 and Co. 516, the latter five being thin canes having a poor tonnage.

The sucrose content of the following varieties was high during the month of January alone : Co. 444, Co. 511 and Co. 512. Out of these Co. 511 and Co. 512 are the best.

The following varieties have shown a high sucrose content during the month of March alone : Co. 281, Co. 313, Co. 344, Co. 347, Co. 366, Co. 382, Co. 419, Co. 425, Co. 429, Co. 430, Co. 505 and Co. 510.

Out of the 61 sugarcane varieties planted last year, Co. 394 was destroyed by white ants. Fresh material of Co. 534, Co. 441 and Co. 442, which were damaged by white ants, was received again in March 1939 for trial along with the following additional ten new varieties : Co. 451, Co. 454, Co. 456, Co. 457, Co. 458, Co. 459, Co. 546, Co. 547, Co. 548 and Co. 549.

Co. 285 was received from the Agricultural Sub-station, Karnal, and Co. 312 and Co. 244 were received from the Sugarcane Research Station, Muzaffarnagar, for inclusion in the yield trial experiment.

The following 12 Co. varieties were selected and planted in March 1939 in randomised blocks to test their tonnage yields under Delhi conditions : Co. 312, Co. 313, Co. 331, Co. 381, Co. 511, Co. 244, Co. 421, Co. 512, Co. 508, Co. 432, Co. 213 and Co. 285.

The rest of the sugarcane varieties were planted on the farm for further observations, and most of them will have to be rejected in due course after proper observations have been made. The general growth of the sugarcane crop was poor due to drought, but it was free from pests and diseases, and it ripened early.

The results of analyses of the sugarcane juice done in the months of January and March 1939 are as follows :—

Percentage of sucrose content in juice of sugarcane varieties grown during 1938-39

Varieties	January	March	Varieties	January	March
			Co. 427	18.44	18.85
Co. 210	18.29	18.46	Co. 428	18.83	18.71
Co. 213	14.16	16.87	Co. 429	17.98	19.29
Co. 281	18.22	19.13	Co. 430	17.37	19.36
Co. 299	18.85	18.78	Co. 431	16.25	17.18
Co. 312	16.74	..	Co. 432	17.27	17.85
Co. 313	18.44	19.23	Co. 433	17.26	17.21
Co. 331	15.86	18.10	Co. 434	19.55	19.65
Co. 336	15.68	18.73	Co. 441	16.46	..
Co. 344	17.74	19.32	Co. 442	15.98	..
Co. 347	15.10	19.15	Co. 443	17.75	..
Co. 348	17.35	18.03	Co. 444	19.78	..
Co. 366	16.73	19.49	Co. 445	16.78	15.34
Co. 368	17.58	18.17	Co. 500	19.57	19.65
Co. 370	16.89	18.12	Co. 501	19.10	20.00
Co. 371	..	18.07	Co. 502	17.76	18.22
Co. 374	19.77	19.10	Co. 503	19.58	19.20
Co. 377	18.17	18.58	Co. 504	16.83	16.90
Co. 378	19.08	19.99	Co. 505	18.94	19.91
Co. 381	17.98	..	Co. 506	19.35	19.08
Co. 382	17.33	19.41	Co. 507	17.48	18.83
Co. 384	16.69	17.52	Co. 508	19.87	21.09
Co. 386	16.58	18.59	Co. 509	18.29	18.21
Co. 391	13.98	17.04	Co. 510	18.84	19.99
Co. 413	15.06	16.38	Co. 511	20.41	..
Co. 417	16.18	16.97	Co. 512	20.20	..
Co. 419	17.47	19.60	Co. 513	15.46	14.36
Co. 421	16.85	17.84	Co. 514	14.77	18.50
Co. 423	15.66	16.90	Co. 516	19.12	20.25
Co. 424	11.11	15.66	Co. 535	14.87	..
Co. 425	18.68	19.72	Co. 536	17.22	..
Co. 426	15.55	18.70	Co. 537	14.91	..

Varieties	January	March	Varieties	January	March
Co. 538 . .	15.37	..	Co. 544 . .	16.32	..
Co. 539 . .	15.01	..	Co. 545 . .	16.90	..
Co. 542 . .	16.85	..	Co. 450 . .	17.21	..
Co. 543 . .	10.85	..			

4. SILAGE

The preservation of green fodder as silage has now become a standard practice on the farm. At present *jowar* only is used for this purpose. The details of the five pits filled during the year are given below :—

Statement of the silo pits filled and consumed during the year from June 1938 to May 1939

No. of silo pit	Date of filling	Total green stuff filled	Date of feeding	Quantity of silage obtained	Percentage loss
		Mds.		Mds.	
Bullock Byre—					
No. 1 . . .	26-8-38 to 30-8-38 .	2,866-24-0	1-1-39 to 9-2-39 .	2,472-17-0	13.7
No. 2 . . .	1-8-38 to 7-8-38 .	2,787-29-0	10-11-38 to 31-12-38 .	2,669-6-0	4.2
Dry Stock—					
No. 1 . . .	1-9-38 to 4-9-38 .	2,932-20-0	Unopened . . .	...	...
No. 2 . . .	12-9-37 to 14-9-37 .	2,469-17-0	1-9-38 to 25-9-38 .	2,129-0-0	13.8
Milk Byre—					
No. 1 . . .	6-9-38 to 10-9-38 .	3,166-10-0	2-6-39 to 25-7-39 .	2,816-5-0	11.1
No. 2 . . .	11-9-38 to 16-9-38 .	3,446-32-0	9-2-39 to 26-3-39 .	3,109-38-0	9.8

During the period of shortage of green berseem in the first half of the cold weather, the milk yield of the Sahiwal herd was kept up by feeding silage only as no other green fodder was available.

5. CROPS GROWN FOR OTHER SECTIONS OF THE INSTITUTE

The following crops were grown for the Imperial Entomologist during the year for the study of insect pests :—

Kharif—Lady's finger, chilli, melon, sponge-gourd, bottle-gourd, *jowar* (*Andropogon Sorghum*), maize, pigeon-pea, castor, brinjal, paddy, cowpeas, soybean, sesame, *mung* (*Phaseolus radiatus*), *urid* (*P. mungo* var. *Roxburghii*), sann-hemp, cotton and sugarcane.

Rabi—Brinjal, chilli, tomato, tobacco, cabbage, cauliflower, turnip, knol-kohl, raddish, carrot, spinach, peas, brassica varieties (*taramira*, *sarson* and *toria*), gram, holly-hock and linseed.

An acre of sugarcane varieties was grown for the Plant Pathologist for the study of mosaic disease.

Half an acre of sugarcane Co. 313 was planted for the Imperial Agricultural Chemist in March 1939 for the study of sugarcane chemistry and manufacture of sugar by the activated carbon method.

A field experiment was conducted for the Imperial Agricultural Chemist for the study of the process of nitrogen fixation by the maize plant.

An acre was planted under sugarcane varieties in March 1939 for the Biological Control Research Officer for the study of sugarcane pests.

6. SEED SUPPLY

The main work of multiplication and distribution of seeds of improved varieties of crops is done at the Agricultural Sub-station, Karnal. A small quantity of seed was also distributed from Delhi as detailed below :—

Variety of crops	Quantity (lb.)	Variety of crops	Quantity (lb.)
Wheat P. 12. . . .	7,405·20	Berseem	47·31
Wheat P. 165 . . .	1,032·61	Soybean yellow . . .	0·50
Oats B. S. 1 . . .	12,321·43	Soybean black . . .	0·50
Gram Pusa T. 25 . .	1,151·92	Soybean chocolate . . .	0·50
		Sugarcane setts . . .	39,350·41

II. FIELD EXPERIMENTS

1. BERSEEM EXPERIMENTS

Two experiments, one for the production of seed and the other for determining the optimum irrigation interval, were carried out on the same lines as reported last year.

(i) *Berseem seed production experiment.*—This experiment was conducted on identical lines both at Delhi and Karnal. It consisted of six randomised blocks, each block having five treatments, A, B, C, D and E. The plots set apart for A were cut only once in January ; those for B, cut twice—once in January and again in February ; C, cut thrice—January, February and March ; D, cut four times—January, February, March and April and E, cut five times—January, February, March, April and May. The experiment was unsuccessful at Delhi due to the early break of monsoon. The results obtained at Karnal are given below :—

Treatments	Mean yield of seed per plot in lb. (·022 ac.)	Percentage on general mean	' z ' test	Critical difference
Berseem seed obtained after—				
A—1st cutting (Jany.).	10·44	163·56	Significant at the 1% level.	1·737 (P = ·05) 2·368 (P = ·01)
B—2nd „ (Feby.)	9·16	143·46		
C—3rd „ (Mar.)	9·50	148·84		
D—4th „ (April)	8·30	130·09		
E—5th „ (May)	0·90	14·05		

Conclusions :—A, B, C and D > E ; A > D ; A = B = C.

It will be seen that the maximum quantity of seed was obtained this year when the crop was left for seed after the first cut, taken in the beginning of January, which is in conformity with the weather conditions prevailing at the end of year. The early crop had a better chance of developing and ripening seed than the late crop owing to early rainfall.

The yields of berseem seed obtained from the experimental plots at Delhi are given below. The stuff harvested from each plot could not be

threshed individually due to rains; they were threshed in five different lots according to the treatments.

Berseem seed obtained after								Total yield of seed in lb. (.132 acre)
1st cutting (January)	.	.	.	.	.	.	.	20.06
2nd „ (February)	.	.	.	.	.	.	.	18.51
3rd „ (March)	.	.	.	.	.	.	.	13.37
4th „ (April)	.	.	.	.	.	.	.	4.63
5th „ (May)	.	.	.	.	.	.	.	2.06

(ii) *Irrigation experiment on berseem, Top Block No. 1.*—The experiment was conducted in six randomised blocks.

Treatments	Mean yield of green fodder per plot in lb. (.022 acre)	Percentage on general mean	'z' test	Critical difference
Irrigations at—				
A—8 days' interval .	1,396.8	113.01	Significant at the 5% level	214.50
B—10 „ „ .	1,186.7	96.01		(P=.05)
C—12 „ „ .	1,361.5	110.15		292.54
D—16 „ „ .	1,170.0	94.66		(P=.01)
E—20 „ „ .	1,065.0	86.17		

Conclusions :—A=B=C ; A>D=E ; C>E.

It is evident from the results given above that there are no significant differences among the irrigation intervals of 8 days, 10 days and 12 days, and this confirms the results obtained last year.

2. VARIETAL YIELD TRIALS

(i) *Yield trial with wheat, Middle Block A.*—The trial was carried out in six randomised blocks.

Varieties	Mean yield of grain per plot in lb. (.017 ac.)	Percentage on general mean	'z' test	Critical difference
Pusa 4 . . .	17.04	99.03	Not significant	6.836 (P= .05)
Pusa 12 . . .	19.73	114.65		
Pusa 80.5 . . .	15.79	91.77		
Pusa 111 . . .	16.85	97.94		
Pusa 114 . . .	15.38	89.35		
Pusa 120 . . .	16.65	96.73		
Pusa 125 . . .	15.42	98.59		
Pusa 165 . . .	17.88	103.87		
Local . . .	17.44	101.33		
8A . . .	18.25	106.05		
C. 518 . . .	18.50	107.51		
C. 591 . . .	17.58	102.18		

Conclusions :—Differences between the varieties are not significant.

The three high yielding varieties, arranged in order of performance, are Pusa 12, C. 518 and 8A as against C. 518, C. 591 and 8A of the last year.

(ii) *Yield trial with gram, Middle Block A.*—The experiment was laid down in six randomised blocks.

Varieties	Mean yield of seed per plot in lb. (.0167 ac.)	Percentage on general mean	'z' test	Critical difference
A—Pusa T. 17 . . .	28.67	113.18	Significant at the 1% level.	7.368
B—Pusa T. 25 . . .	30.00	118.45		($P = .05$)
C—Pusa T. 28 . . .	14.96	59.06		9.887
D—Pusa T. 58 . . .	32.79	129.47		($P = .01$)
E—P. F. 3	26.58	104.96		
F—P. F. 6	23.00	90.81		
G—P. F. 11	26.63	105.12		
H—P. F. 17	20.00	78.96		

Conclusions :— $A = B = D = E = G$; $A = B = D > C = H$; $D > C = F = H$; $E, F \text{ \& } G > C$.

The three high yielding varieties, arranged in order of performance, are Pusa T. 58, Pusa T. 25 and Pusa T. 17 as against Pusa T. 25, Pusa T. 58 and P. F. 3 of the last year.

(iii) *Yield trial with cold weather fodder crops, Middle Block A.*—The undermentioned six *rabi* fodder crops were tested for their yield in six randomised blocks, and, as will be seen from the results given below, berseem excelled all other crops. Berseem was cut once in each month from December to May, yielding green fodder throughout the cold weather and thus compensated for the largest number of irrigations given to this crop.

Varieties	No. of irrigations given	No. of cuttings	Mean yield of green stuff per plot in lb. (.0148 ac.)	Percent- age on general mean	'z' test	Critical differ- ence
A—Berseem	21	6	888.8	219.35	Significant at the 1% level.	86.21
B— <i>Senji</i> (<i>Melilotus</i> sp.).	12	2	225.5	55.65		($P = .05$) 117.58 ($P = .01$)
C— <i>Methra</i> (<i>Trigo- nella</i> sp.).	10	2	202.7	50.01		
D— <i>Kerao</i> (Peas) . . .	6	1	398.0	98.22		
E— <i>Khesari</i> (<i>Lathy- rus</i> sp.).	6	1	314.8	77.69		
F— <i>Barley</i> and <i>Kerao</i>	7	1	401.5	99.08		

Conclusions— $A > B, C, D, E \text{ \& } F$; $D = E = F > B = C$; $F > B, C \text{ \& } E$.

3. MISCELLANEOUS EXPERIMENTS

(i) *Manurial experiment, Main Block No. 5.*—A manurial experiment was conducted under maize to test activated sludge against farmyard manure and rape cake. As a portion of the crop was destroyed by the hairy caterpillar, no conclusive results could be drawn from the experiment. The experiment will be repeated next year.

(ii) *Determination of the best time for sowing gram, Middle Block A.*—Gram Pusa T. 25 was sown on different dates to test its germination and subsequent yield. The early sown plots were poor in germination and also the percentage of wilted plants in them was greater than those in the other plots. The experiment was laid down in six randomised blocks and the results are given below :—

Treatments	Mean yield of seed per plot in lb. (.0064 ac.)	Percentage on general mean	' z ' test	Critical difference
Plots sown on—				
A—23rd Sept. 1938 .	1.667	25.72	Significant at the 1% level	2.043
B—30th Sept. „ .	5.208	80.39		(P = .05)
C—7th Oct. „ .	6.958	107.40		2.787
D—14th Oct. „ .	8.667	133.76		(P = .01)
E—21st Oct. „ .	8.417	129.90		
F—28th Oct. „ .	7.958	122.83		

Conclusions :—D=E=F>A and B ; B=C>A.

III. MACHINERY AND IMPLEMENTS

1. TESTING OF IMPLEMENTS

1. *The A.-G. B. general cultivator and bullock hoe*, which was received back from the makers after incorporating a number of suggestions made by the Imperial Agriculturist, worked satisfactorily. The implement is now a perfect one.

2. *The Mechanical seed drill* received from the Research Engineer, Coimbatore, was tested and tried for sowing wheat and was found unsatisfactory—the main defect was that the seed-distributing discs were not revolving freely on account of their getting choked. The machine was returned to the inventor.

3. *Resistance of soil to bullock-drawn implements.*—The collection of country ploughs from all the provinces was nearly completed, and draught tests were started by means of a Recording Traction Dynamometer lent by Messrs. Dunlop Company, Calcutta.

The results of some of the tests carried out on unreplicated basis are given below :—

Draught test of ploughs by means of a recording traction dynamometer

Date of trial	Name of plough	Class of soil	Class of work	Class of bullocks used	Average pull	Time	Distance	Miles per hour	Power exerted	Remarks
28-9-38	Indore	Lower stubbles broken by disc harrow in Plot No. 14.	Ploughing	Sahwal	lb.	Second	Ft.		H. P.	White spring with main piston in the recorder.
					54	142	1.79	1.42		
	Bareilly				54	142	1.79	1.41		
					60	142	1.60	0.52		
	Oudh				65	142	1.49	0.71		
	Jhansi				60	142	1.60	0.74		
	N.-W. F. Province				55	142	1.76	1.13		
	Sabour				50	142	1.94	1.84		
	Rajah				50	142	1.94	1.76		
	Punjab				50	142	1.94	0.96		
29-9-38	Gurgaon				185	50	142	1.94	1.80	Red spring with the main piston in the recorder.
	Monsoon				348	50	142	1.94	1.87	
	Bhar				202	60	142	1.61	1.74	
	Victory				405	60	142	1.61	1.74	
	Shanti				185	50	142	1.94	0.96	
	Pusa bar				252	55	142	1.76	1.18	
	Delhi (Dest)				210	52	142	1.86	1.04	

The moisture contents of the soil on which the test was carried out are as follows :—

	% Moisture.
East	5.8
Middle	7.7
West	6.2
North	8.0
South	7.4

The soil, on an average, was very dry and hard up to $2\frac{1}{2}$ inches, and after that it was softer than the top soil.

We have now purchased our own Dynamometer and further tests will be carried out with all the country ploughs collected from the various provinces.

2. TRACTORS

We are now at the third stage in the motor tractor line. The following two types of high power 4-cylinder diesel tractors are on trial.

1. W. D. 40 McCormick Deering.
2. Hanomag 55 H. P., crawler type.

Two W. D. 40 McCormick Deering tractors are working at the Agricultural Substation, Karnal ; and the details of working are given in report of the Substation.

The Hanomag 55 H. P. was purchased in March 1937 along with a 4-furrow John Deere plough, and has since been working at the main farm at Delhi. It has so far been noticed that the fuel system is not satisfactory in this tractor. The engine stops suddenly and does not start until the fuel nozzle is overhauled or changed altogether. It requires changing of piston rings more often than usual. The details of work are given below :—

Hanomag tractor
Summary of work done

Year	Working hours	Ploughing		Disc-harrowing		Grubbing	
		Hours	Acres	Hours	Acres	Hours	Acres
1936-37	153	87-00	86-00	28-00	44-31	38-00	97-00
1937-38	372	193-50	191-00	34-50	60-00	144-00	357-94
1938-39	410	13-00	12-00	262-00	534-00	135-00	246-00

Acreage per hour

Year	Ploughing	Disc-harrowing	Grubbing
1936-37	0-99	1-58	2-55
1937-38	0-99	1-74	2-49
1938-39	0-92	2-04*	1-82†

*10 ft. disc harrow was used against 8 ft.
† 8 ft. grubber was used against 10 ft. field cultivator.

Fuel consumption

Year	Crude oil		Kerosene oil		Petrol		Engine and G. oil		Grease		Waste cotton	
	Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total lb.	Per hour lb.	Total lb.	Per hour lb.
1936-37	259-30	1-69	24-00	0-16	2-00	0-01	8-62	0-06	45-00	0-29	9-00	0-06
1937-38	631-75	1-70	37-42	0-10	12-00	0-03	48-43	0-13	78-00	0-21	18-00	0-04
1938-39	621-25	1-52	9-54	0-02	7-00	0-02	76-88	0-19	86-00	0-21	27-00	0-07

Analysis of total cost

Year	Crude oil	Kerosene oil	Petrol	Lubricants and waste	Wages of mistry and water carrier	Wages of regg. staff	Spare parts	Total	Expenses per hour
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
1936-37	106 9 9	25 10 6	3 4 0	19 9 3	55 0 0	...	...	210 1 6	1 6 0
1937-38	286 4 0	80 0 0	18 12 0	135 5 0	68 5 0	90 0 0	266 8 0	895 2 0	2 6 6
1938-39	279 8 9	7 8 3	10 15 0	188 0 0	94 12 0	129 6 0	371 8 0	1,081 10 0	2 10 3

Cost per acre

Year	Ploughing			Disc-harrowing			Grubbing		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
1936-37	1	6	3	0	13	11	0	8	8
1937-38	2	6	11	1	6	10	0	15	6
1938-39	2	13	11	1	4	8	1	7	2

3. MEDIUM TYPE MOTOR TRACTORS

After an extensive trial and testing of light type motor tractors, such as Fordson, Austin, Cletrac, the working details and life histories of which have been published in the Annual Report of the Imperial Agriculturist for 1927-28 and in the Pusa Bulletin No. 194, the following medium-size wheel-type motor tractors were introduced for testing their usefulness in agricultural work.

(1) *The International McCormick Deering*, kerosene oil, 15-30 H. P. tractor was purchased in January 1927. It was used for both cultivation and belt pulley and has worked with complete success throughout. The total cost of spare parts for 2,364·21 working hours is Rs. 1,889-10-1. No difficulty was experienced in getting spare parts, and no serious trouble occurred during the working seasons. Among the kerosene oil types, this tractor has proved the most reliable one.

(2) *The Ransomes Vicker's, Mark 3*, kerosene oil, 23-40 H. P. tractor was purchased in December 1928 to work against the International tractor. This tractor, Mark 3, was found defective in many respects, and it was reported to the manufacturers. Messrs. Vickers, Ltd., agents for this tractor, took back this model and replaced it by another tractor, Mark 4, without any extra cost.

The arrangement for spare parts supply was not satisfactory, but as the International tractor parts fitted this tractor, no serious handicap was experienced in this respect. Due to its running at a very high speed there was too much of wear and tear and high fuel consumption. After working for 1,629·37 hours, during which time spare parts worth Rs. 2,365-15-2 were required, the machine became unfit for further service.

(3) In 1930 the tractor problem assumed a different aspect, when crude-oil tractors running on lower grade cheap crude-oil were introduced. The *Lanz Bulldog*, semi-diesel, single cylinder type, 15-30 H. P. tractor was purchased in November 1930. As the listed H. P. of 15-30 did not correspond to the rated H. P. of the McCormick Deering kerosene oil tractor, the Lanz Bulldog could not pull the 4-furrow plough which is drawn by the McCormick Deering. It was, therefore, worked with a three-furrow plough. During the period 1930-38, it worked smoothly for 2,336·79 hours and used spare parts worth Rs. 2,384-11-9. The engine, having no cylinder liner, was a great disadvantage. When the cylinder was worn out, a complete new cylinder and piston had to be fitted, while it would have been a clear saving had it fitted a new cylinder liner only. It was very easy to start by a blow lamp like an ordinary oil-engine.

(4) *The Marshall*, semi-diesel, single cylinder type 15-30 H.P. tractor, which was purchased in June 1932, began to give considerable trouble from the very beginning due to the fuel pump cam slipping on sleeve and thereby making injection late. This tractor was also changed with a 18-30 H. P.

model on which the cam and sleeve were solid. The new model also proved unsatisfactory due to the faulty lubricating system, and cold starting by ignition cartridge made it difficult to start. The defect in the lubrication system ultimately led the cylinder to crack, which, to replace, would cost half the price of the tractor.

The statements showing consumption of fuel, etc., and the summary of work done by these tractors are given below :—

Summary of work done by the different tractors from the date of purchase

Class of work	McCormick kerosene oil (1927-1935)			Vicker kerosene oil (1920-1935)			Lanz Bulldog crude oil (1930-1938)			Marshall crude oil (1932-1935)		
	Hour	Acres	Acres per hour	Hours	Acres	Acres per hour	Hours	Acres	Acres per hour	Hours	Acres	Acres per hour
Ploughing .	511.41	483.63	0.95	432.58	532.90	1.23	789.01	667.96	0.84	237.20	242.14	1.02
Disc-harrowing .	1,123.41	2,030.00	1.81	978.82	1,989.49	2.03	595.08	1,042.62	1.75	118.41	232.58	1.96
Grubbing .	530.71	1,013.33	1.91	114.90	211.16	1.84	670.20	1,152.80	1.72	392.75	743.83	1.89
Rolling .	117.66	184.65	1.57	6.25	22.12	3.54	148.25	483.25	3.26	31.00	101.38	3.27
Drilling .	51.08	137.00	2.68	96.82	261.35	2.70	6.00	11.36	1.89	81.00	237.00	2.92
Harrow ploughing	28.00	50.00	1.79	...	...	...	...	...	...	98.55	181.00	1.84
Reaping .	...	...	...	...	...	...	22.00	66.00	3.00	...	...	...

Statement showing the consumption of fuel, lubricating oil, etc., in different tractors from the date of purchase

Name of Tractor	Total hours worked	Kerosene oil		Petrol		Crude oil		Lubricating and gear oil		Grease		Waste cotton		Total cost of spare parts
		Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total Gall.	Per hour Gall.	Total lb.	Per hour lb.	Total lb.	Per hour lb.	
McCormick Deering (K. oil).	2,364.27	5,194.04	2.20	173.91	0.07	...	...	454.40	0.19	390.17	0.17	140.84	0.06	Rs. A. P. 1,189-10-1
Vicker (K. oil)	1,629.37	5,137.87	3.15	136.16	0.08	...	...	333.37	0.20	301.00	0.18	131.14	0.08	2,365-15-2
Lanz Bulldog (crude oil).	2,336.79*	170.11	0.07	...	...	3,731.82	1.60	371.45	0.16	443.87	0.19	203.00	0.09	2,384-11-9
Marshall (crude oil)	958.91	22.22	0.02	...	...	1,315.70	1.37	190.07	0.20	161.50	0.17	60.62	0.06	1,538-6-7

* Including 97.25 hours belt pulley work.

Cost per acre

Name of Tractor	Cost of Tractor	Total cost of working including spare parts	Expenses per hour	Cost per acre						
				Ploughing	Disc-harrowing	Grubbing	Rolling	Drilling	Reaping	Harrow ploughing
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
McCormick Deering.	5,445 2 0	8,528 13 3	3 9 9	3 12 10	1 15 11	1 14 3	2 4 10	1 5 7	...	2 0 4
Vicker	6,222 0 0	8,541 2 6	5 3 10	4 4 2	2 9 3	2 13 7	1 7 8	1 15 0	...	...
Lanz Bulldog	6,087 7 0	6,303 9 6	2 11 2	3 3 6	1 8 8	1 9 1	0 13 3	1 6 9	0 14 5	...
Marshall	4,655 0 0	1,538 6 7	1 9 8	1 9 1	0 13 1	0 13 7	0 7 10	0 8 10	...	0 13 11

4. GENERAL REMARKS ON TRACTOR WORKING

It is not necessary that the tractor driver should be an expert mechanic, but he should take keen interest in his machine. In the busy season, costly breakdowns can be avoided through a little care on the part of the driver towards the lubrication of the engine and the cooling system.

During the working hours, whenever the tractor is stopped for fuel or water, the oil level should be checked and the cause of excessive consumption should be investigated. The safest policy would be to change the crank case oil in a kerosene oil tractor at every 100 hours of work, and it should be drained out warm. Oil filters should be occasionally taken out and cleaned of sludge and other solid matter.

As regards the gear box which contains a large number of ball or roller bearings, care should be taken that dirt or any foreign matter does not get in when putting in the gear oil. In the case of parts fitted with grease cups or grease gun nipples, the driver should go round the tractor every day giving a turn to the grease cup and applying grease gun to the nipples until the grease begins to ooze out at the other end of the bearing. The nipples should be cleaned first, before using the grease gun.

In regard to the cooling system, the radiator should be kept full. The water level should not be allowed to get below the bottom of the upper tank, otherwise circulation will be stopped. The fan belt should be kept tight to prevent it from slipping.

The next most important thing is the air cleaner, whether oil or water operated, which must not be neglected, specially under Indian conditions, where tractors are to work in dusty fields, and it is absolutely necessary to clean out accumulated dust every day and to keep the oil or water to its proper level.

IV. CATTLE BREEDING

1. THE PEDIGREE SAHIWAL HERD

At the close of the year the herd consisted of 68 cows, 10 bulls, 48 young male stock and 69 heifers—a total of 195 head.

In the month of December, foot-and-mouth disease broke out in the herd, and, as a result, there was a temporary drop in the milk yield, and in a few cows complete suppression of milk. A sporadic case of black-quarter in a cow resulted in its death. In the month of October, calf pneumonia (*Corynebacterium pyogenes bovis*) and coccidiosis broke out among the pail-fed calves under two weeks old, and this was responsible for twelve deaths,

The herd was protected against rinderpest with goat tissue virus and also against black-quarter with black-quarter vaccine:

At the Second All-India Cattle Show held at New Delhi in February 1939, eleven animals secured prizes and places in the Sahiwal class out of 22 cattle exhibited from this herd. One of our proved early maturity bulls, Lakhan, had the unique distinction of winning the champion cup for the best milch bull in the Show and also first prize for the best bull in the Sahiwal class and second place for the best bull in the Show.

List of prize winners at the Second All-India Cattle Show

1939

1938

Name	Class	Place secured	Name	Class	Place secured
Lakhan . . .	Bull .	I and champion.	Firad . . .	Bull .	I
Firad . . .	Do. .	II .	Lakhan . . .	Do. .	III
Tarzan . . .	Youngbull	I .	Cholesari . . .	Cow	IV
Federation . . .	Do. .	III .	764 . . .	Heifer .	I
Nalcham . . .	Young cow.	II .	760 . . .	Do. .	III
Rajsuri . . .	Do. .	III			
Mabri . . .	Do. .	IV			
Naruli . . .	Cow .	II			
Machrama . . .	Do. .	IV			
799 . . .	Heifer .	III			
790 . . .	Do. .	IV			

2. MILK YIELD

The drought conditions which prevailed during the months of October and November had an adverse effect on the general milk yield of the herd. A combination of such unavoidable factors reduced the average milk yield of the herd to 21.2 lb. per cow per day, as compared with 22.2 lb. of the last year. Even under all such adverse conditions the herd remained in excellent health throughout the year.

Statement of milk yield for the year 1938-39

Month	Average yield			No. of cows in milk and dry			
	Total yield lb.	Per day lb.	Per cow per day lb.	Total No.	In milk	Dry	Percentage of cows in milk
July 1938 . . .	23,754	766	21.1	64	36	28	56.3
August . . .	20,911	675	20.7	65	33	32	50.8
September . . .	22,992	766	20.0	69	38	31	55.1
October . . .	26,824	865	20.7	65	42	23	64.6
November . . .	26,033	868	20.5	62	42	20	67.7
December . . .	24,036	775	20.2	65	38	27	58.5
January 1939 . . .	23,463	757	20.1	68	38	30	55.9
February . . .	21,975	785	20.2	71	39	32	54.9
March . . .	25,594	826	21.2	61	39	22	63.9
April . . .	28,755	958	24.3	60	39	21	65.0
May . . .	31,034	1,001	23.3	65	43	22	66.2
June . . .	31,982	1,066	21.6	33	49	14	77.8
Total . . .	307,353	10,108	253.9	778	476	302	736.7
Average . . .	25,613	842	21.2	65	40	25	61.4
Average for 1937-38 . . .	29,124	958	22.2	73	43	29	59.8

Average yield per cow per day, of second calvers was 18.6 lb. and that of heifers 18.2 lb., as against 20.3 lb. and 17.8 lb., respectively, for 1937-38,

The performances of some of the best cows and heifers are given below. Chengi No. 534 gave 10,036 lb. in 304 days in her seventh lactation.

Some of the cows and heifers which completed lactation during 1938-39

Serial No.	Name & No.	Date of birth	No. of calving	Lactation lb.	days
<i>Cows—</i>					
1	Chengi 534	11-11-25	7	10,036	304
2	Charoochi 667	10-9-32	3	9,464	304
3	Chansuri 653	11-3-32	4	8,890	303
4	Naraee 705	22-12-33	2	8,139	303
5	Choki 681	11-3-33	3	7,949	306
6	Mukta 472	27-6-23	7	7,729	304
7	Makhi 557	14-10-26	8	7,320	294
8	Naruli 665	12-8-32	3	7,216	304
9	Bulbul 814	9-2-28	6	7,017	303
10	Chaplari 702	10-11-33	2	6,705	304
11	Cholesari 717	16-3-34	2	6,678	304
12	Chandra 456	27-10-22	10	6,673	304
13	Chakai 563	11-1-27	6	6,604	303
14	Bripla 649	5-1-32	4	6,533	306
15	Brukhta 654	19-3-32	4	6,519	306
16	Cholbani 695	4-6-33	2	6,451	304
17	Noshni 686	8-4-33	3	6,364	282
18	Cholmi 677	17-2-33	3	6,029	304
<i>Heifers—</i>					
1	Lakhram 753	11-8-35	1	7,440	304
2	Nalcham 751	2-6-35	1	6,405	304
3	Manoshi 754	16-8-35	1	6,270	306
4	Lengi 746	11-4-35	1	6,165	303
5	Erenggee 764	13-1-36	1	5,823	306
6	Narbiri 755	18-8-35	1	5,308	266
7	Lakhamdhi 765	8-2-36	1	5,248	304
8	Nalakhi 748	25-5-35	1	5,198	304

3. CALF REARING

During the year under report 55 calves were reared out of 67 born as against 66 calves reared out of 67 dropped in the previous year. The abnormal number of deaths was due to the severe outbreak of calf pneumonia and coccidiosis breaking out simultaneously among the calves under a fortnight old. During this outbreak twelve calves died out of thirteen attacked with one recovery only. The calf mortality due to common ailments among them was nil against 1.5 per cent. of the previous year, whereas mortality due to infectious diseases was 17.9 per cent. during the year under report.

Percentage of mortality amongst the pair-fed calves for 1938-39

Year	Births	Deaths	Percentage of mortality
1937-38	67	1	1.5
1938-39	67	12	17.9

4. EARLY MATURITY EXPERIMENTS

The early maturity cows continued to maintain their high level of health and condition for high production. The percentage of heifers performing below 400 gallons is now quite insignificant. The average yield of heifers was 18.2 lb. per head per day, as compared with 17.8 lb. last year.

The results to-date show that we have now reached a standard in which we have age, weight, and constitution—all properly balanced and considered—and the heifers are now giving increased yields and showing no signs of strain.

5. SALE OF CATTLE

The ever increasing demands for our pedigree cattle could not be adequately met with from the limited stock of this breeding herd. Internal demands were partially met from the surplus stock. Under the present arrangement there is not sufficient stock to meet the demands from abroad. In view of the western countries' endeavour to raise the butter fat content of the milk of their cattle, there will be a market hereafter for the disposal of our young male stock. A few inquiries on this subject are being dealt with.

The outstanding transaction effected during the year under report was the sale of the proved bull Cholmondely to the Government of U. P. for Rs. 2,700 which is the record price ever fetched in India for an Indian pedigree stud bull.

In all 52 head of cattle were sold for Rs. 7,869-12-0 as against 35 head of cattle for Rs. 5,920 of the previous year.

Statement of cattle sold during the year 1938-39

Particulars	No.	Total price	Average			Average for 1937-38		
		Rs.	Rs.	A.	P.	Rs.	A.	P.
1. Cows	17	3,155	185	9	0	188	3	0
2. Bulls	2	3,000	1,500	0	0	350	0	0
3. Young bulls	16	1,465	91	9	0	90	7	0
4. Steerings.	8	130	16	4	0	..		

Nine animals were sold on nominal prices.

6. RECEIPTS

An amount of Rs. 22,224-13-0 was realised from the sale of dairy produce cattle, etc., as against Rs. 18,579-2-6 of the previous year. The income from the sale of dairy produce alone fetched Rs. 14,345-1-0. The income derived during the year is the record figure for this herd.

Statement of income for 1935-36 to 1938-39

Year	Dairy produce			Cattle			Miscellaneous			Total		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
1935-36	7,261	9	3	2,035	0	0	90	11	9	9,387	5	0
1936-37	6,507	4	9	4,233	0	0	50	10	6	10,790	15	3
1937-38	12,659	2	6	5,920	0	0	..			18,579	2	6
1938-39	14,345	1	0	7,869	12	0	10	0	0	22,224	13	0

The annual statement of live-stock is given below :—

Annual statement of live-stock as it stood on the 30th June, 1939

Description of cattle	Number of animals from last year	Increase		Recd. for expt.	Decrease				on June 30th 1939
		By birth	By transfer		By death	By transfer	By sale	Sent to Pinjrapole	
Bulls for breeding . . .	13	..	2	..	1	..	3	1	10
Cows—milch herd . . .	65	..	23	1	4	6	15	1	63
Cows—for breeding . . .	1	..	1	..	..	..	..	..	2
Cows—for sale . . .	5	..	4	..	1	..	6	..	2
Cows—old . . .	..	..	1	..	..	..	..	..	1
Young male stock in Dairy	44	33	..	1	8	13	17	..	40
Young male stock for sale	..	..	8	..	..	..	..	..	8
Young male stock—steerlings	9	..	3	..	..	4	8	..	..
Young female stock in Dairy	65	34	..	..	4	23	3	..	69
Bullocks . . .	4	..	2	..	..	2	..	..	4
Total . . .	206	67	44	2	18	48	52	2	199

V. PROGRAMME OF WORK FOR 1939-40

1. Mixed farming including the study of rotations for building up the soil to a high level of fertility.
2. The study of irrigated and unirrigated crops.
3. Investigations on fodder crops for soiling, hay, silage and green fodder and their seed production.
4. Conduct of field experiments for testing manures and crops including sugarcane.
5. Dynamometer investigations on the resistance of soil to bullock-drawn implements.
6. Testing of agricultural implements and machinery.
7. Conduct of experiments for other sections of the Institute.
8. Continuation of cattle-breeding operations on the pedigree Sahiwal herd with special reference to the transmission of milch characters.
9. Special feeding of the young stock with a view to early maturity in the Sahiwal herd.
10. Training of post-graduate students.

2. AGRICULTURAL SUBSTATION, KARNAL

I. FARM AND CULTIVATION

1. FARM

The total area of the Substation is about 2,154 acres, out of which 51·42 acres remained under the control of the Sugarcane Expert. The area under direct cultivation of the farm was 1,165·65 acres, while 152 acres in Jodhawala,

60 acres in Plot No. 2-A and 83·50 acres in Plot No. 1 were leased out on cash rent for cultivation and grazing.

The major portion of the area has recently been put under direct cultivation, and therefore, it is not expected to get the normal yield at this stage. Attempts have so far been made to put the land into shape and condition to make it fit for mechanical cultivation.

A big storm-water drain has been constructed from the railway line to the old Jumna Canal. The other field drains in Plot Nos. 7 & 6 are expected to be finished during the next year. As soon as the drainage system of the farm is improved, attention will be devoted for the better lay-out of the arable area, including re-modelling of fields, levelling, straightening of farm roads and irrigation channels, to facilitate cultivation and supervision.

An area of 40 acres in Plot No. 7 (Uchana Block) has recently been broken, thus making the whole of Plot No. 7 cultivable.

The Substation receives its supply of irrigation water from the Western Jumna Canal on a rotation system depending upon the availability of water in the canal. During the year under report, 478·82 acres in *kharif* and 1,076·61 acres in *rabi* were irrigated. The poor yields of crops during this year are attributed, to a great extent, to the late opening of the canal and less and irregular supply of water.

2. RAINFALL AND CROP YIELDS

The total rainfall during the year under report amounted to 21·36 inches as against 23·55 inches of the previous year and 29·34 inches in 1936-37.

The crop yields under direct cultivation were as follows. The yields of the previous year are given in brackets.

Statement of crop yields during 1938-39

Crops	Area in acres	Yield in maunds	
		Total	Average per acre
Maize—Corn	3·30	39·95	12·11 (9·60)
Maize—green fodder	150·30	16,948·60	112·77 (129·76)
Jowar—green fodder	159·08	28,981·43	182·18 (174·30)
Jowar—seed	4·56	41·75	9·16 ..
Meth	5·40	17·73	13·29 ..
Soybean	1·48	14·53	9·82 (7·85)
Cowpeas	1·48	7·13	4·82 (5·20)
Sannhemp—seed	5·51	26·05	4·73 (8·69)
Paddy	22·52	544·55	24·18 (15·03)
Cotton	0·30	1·61	5·37 (9·87)
Oats	446·58	6,564·68	14·70 (18·25)
Wheat	246·36	3,841·33	15·59 (22·74)
Barley	37·85	758·40	20·04 (9·56)
Gram	231·84	2,442·73	10·54 (9·19)
Flax—seed	8·78	87·45	9·96 (9·43)
Peas	1·07	26·98	25·21 (1·60)
Sarson	3·68	49·08	13·34 ..
Berseem—green fodder	21·56	9,569·78	443·87 (620·38)

The fodder crops like maize, soybean, *meth*, cowpeas and *jowar* grow successfully at Karnal. In the *rabi* cropping, berseem has been a great success. Amongst other crops, eight varieties of Pusa wheat were tried, and P. 165, as usual, gave good results. This variety and also P. 144 were badly affected with bunt. The wheat rust was also severe this year and P. 4, P. 12, P. 111 & P. 114 suffered most from this disease, and the attack was least in P. 165. In barley, Pusa T. 13 was found to be a better yielder than the other varieties. Gram did not do well due to the lack of moisture and prevalence of wilt. Eight acres of berseem were left for seed, and it is expected to thresh out good seed at the rate of 5-6 maunds per acre.

3. FIELD EXPERIMENTS AND MISCELLANEOUS WORK ON CROPS

The following experiments were conducted during the year under report :—

- (a) The manurial experiment with sulphate of ammonia, nitrate of soda and their mixture on three varieties of paddy was repeated this year at the instance of the Imperial Council of Agricultural Research for testing the validity of certain results arrived at by Prof. Dastur. It was found that (i) sulphate of ammonia alone and (ii) the mixture gave a better outturn of grain than nitrate of soda.

- (b) The study of cowpeas was continued on the lines reported last year.

Facilities were provided to the following officers for carrying out their experiments at the Sub-station :—

- (a) The Plant Pathologist—experiments on sugarcane diseases.
- (b) The Assistant Mycologist—experiments on wheat bunt.
- (c) The Imperial Entomologist—experiments on cotton.
- (d) Flax seed was grown on 8.78 acres for the Assistant Fibre Expert, Bengal.

4. TRACTORS AND MACHINERY

The two McCormick diesel tractors worked satisfactorily throughout the year. These are quite useful type of tractors for controlling a big area. Their working details are given below :—

W. D. 40 McCormick Deering Tractors
Summary of work done

Tractor No.	Year	Total working hours	Harrow-ploughing		Disc-harrowing		Grubbing		Ploughing		Drilling		Belt pulley & Miscellaneous work
			Hours	Acres	Hours	Acres	Hours	Acres	Hours	Acres	Hours	Acres	
1612	•	1,033.41	299.00	801.13	398.59	1,069.54	281.16	711.16	80.75	119.60	3.50	9.16	20.41
		1,934.10	281.25	771.97	182.80	513.97	264.80	831.97	3.00	3.75	...	...	202.25
1614	•	1,030.00	476.75	1,356.18	43.00	115.10	275.00	1,013.27	31.75	39.55	...	...	193.50
		1,884.81	475.66	1,251.40	147.38	401.96	206.02	504.75	18.50	38.75	8.00	12.80	29.25
1614	•	933.85	444.90	1,226.64	105.70	325.21	276.32	963.96	...	...	...	...	106.90
		1,093.50	305.00	832.52	260.25	671.70	220.75	779.73	78.25	110.93	...	...	229.25

Acres per hour

Tractor No.

Year

Harrow-ploughing

Disc-harrowing

Grubbing

Ploughing

Drilling

1612	•	•	1936-37	2.68	2.68	2.68	2.53	1.48	2.62
			1937-38	2.74	2.81	2.81	3.14	1.25	•
			1938-39	2.84	2.68	2.68	3.68	1.25	•
1614	•	•	1936-37	2.63	2.73	2.73	2.45	2.09	1.60
			1937-38	2.76	3.08	3.08	3.49	•	•
			1938-39	2.73	2.58	2.58	3.53	1.42	•

Consumption of fuel

Tractor No.	Year	Crude oil		Kerosene oil		Petrol		Engine and gear oil		Grease		Waste cotton	
		Total Gall.	Per hr. Gall.	Total Gall.	Per hr. Gall.	Total Gall.	Per hr. Gall.	Total Gall.	Per hr. Gall.	Total lb.	Per hr. lb.	Total lb.	Per hr. lb.
1612	•	2,072.00	1.91	74.14	0.07	49.00	0.05	95.00	0.09	163.00	0.15	47.25	0.06
		2,072.00	1.84	77.50	0.08	37.00	0.04	120.24	0.13	194.00	0.21	93.75	0.10
1614	•	1,613.00	1.88	78.98	0.08	42.00	0.04	107.66	0.11	284.00	0.31	109.50	0.11
		1,712.00	1.94	66.71	0.07	40.00	0.05	104.00	0.12	283.00	0.16	85.31	0.07
1614	•	1,917.00	2.05	79.70	0.08	40.00	0.04	107.00	0.11	292.00	0.24	83.00	0.09
		2,064.00	1.89	73.22	0.07	32.00	0.03	136.71	0.12	342.00	0.31	112.75	0.10

Analysis of total cost

Tractor No.	Year	Crude oil		Kerosene oil		Petrol		Lubricants & waste cotton		Wages of mechanics and wages carrier		Wages of rearing staff		Spare parts		Total cost		Expenses per hour.	
		Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.	Rs.	A. P.
1612	•	1,284.37	7.10	59.35	1.11	88.11	1.11	271.15	4.4	342.9	4.4	30.0	0.6	127.1	1.10	2,203.7	7.9	2.0	6
		1,854.99	9.9	52.27	1.0	69.3	1.0	322.1	4.4	385.1	4.4	30.0	0.6	109.9	0.8	1,812.7	7.9	1.15	1
1614	•	874.11	4.4	73.81	1.1	69.3	1.1	231.2	2.2	340.2	2.2	61.14	5.0	605.13	7.0	2,356.8	8.1	2.5	0
		1,066.69	9.9	53.07	1.0	69.3	1.0	322.1	4.4	385.1	4.4	118.9	0.0	324.3	3.0	2,272.10	2.2	2.9	1
1614	•	934.11	9.9	52.92	1.0	69.3	1.0	320.10	3.3	375.11	2.2	20.3	0.0	102.15	2.2	1,869.14	4.4	2.0	0
		987.5	8	72.14	5	52.12	10	405.13	2.2	244.5	0	66.14	1.1	137.8	5	1,917.9	7.7	1.12	1

The average milk yield of cows which completed their full lactations during the year is given together with those obtained in the two previous years.

Milk yield of cows which completed their lactations during the last three years

Year	No. of cows	Average milk yield in lb.	Average No. of days in milk
1936-37	69	4,422	276.1
1937-38	56	5,716	284.1
1938-39	60	5,590	281.0

The records of six best cows and six best heifers which completed their lactations during the year are given below:—

Records of best cows and heifers during 1938-39

Name and No.	No. of calvings	Milk yield (lb.)	Days in milk
<i>Cows—</i>			
Thandi 4	10	8,155	305
Kotri 24	8	7,360	305
Fazitan 57	4	7,265	305
Sidhi 58	4	7,560	305
Imli 81	2	7,321	305
Rafikan 88	2	7,455	304
<i>Heifers—</i>			
Poti 113	1	5,855	276
Ruhli 114	1	5,206	286
Parsanni 117	1	6,415	305
Rashi 124	1	5,909	305
Mitri 129	1	6,058	279
Laila 143*	1	4,257	303

3. PRE-MILKING AND HANDLING AND EARLY MATURITY EXPERIMENTS

Sixty-eight cows and 22 heifers which calved during the year were treated and milked before calving as practised on the Delhi herd, and, with a few exceptions, all responded to this treatment and no trouble was experienced before or after calving.

The experiments of special treatment and four times milking against ordinary treatment and two times milking are being continued as desired by the Imperial Council of Agricultural Research.

*Early maturity heifer.

The records of the early maturity heifers are given in the table below :—

Records of early maturity heifers

Name and No.	Date of birth	Age at service Y. M. D.	Weight of calf at birth (lb.)	Performance lb./days	Remarks
Laila 143. . .	16-1-36	1 7 18	47	4257/303	
Razadi 144 . . .	7-2-36	1 8 28	45	2721/246	Had been ill for 1 month.
Lali 154 . . .	30-6-36	1 8 12	54	2641/189	Giving 13 lb. daily.
Roti 142 . . .	7-1-36	1 9 27	40	No milk	
Ushni 165 . . .	25-10-36	1 7 1	45	No milk	
Utakni 162 . . .	18-10-36	1 9 7	50	1101/56	Giving 20 lb. daily.
Lado 176 . . .	30-1-37	1 6 20	45	782/35	Giving 26 lb. daily.
Lasni 173 . . .	15-1-37	1 7 8	44	451/28	Giving 18 lb. daily.

4. CALF REARING

There were 89 births during the year, and all calves were weaned at birth and reared on pail. The percentage of mortality amongst pail-fed calves is seen from the table given below :—

Mortality amongst pail-fed calves during 1938-39

Year	No. of calves reared	Deaths	Mortality per cent
1937-38	152	15	9.9
1938-39	159	25*	15.7†

The calf weightment figures are given below :—

Average weight of calves at birth and at one year's age

Year	No. of calves born	Average weight at birth (lb.)	No. of calves completed one year's age	Average weight at one year's age (lb.)	Average weekly increase from birth to one year (lb.)
1937-38	86	49.7	66	510.2	9.8
1938-39	89	47.7	70	461.8	8.9

5. SALE OF CATTLE

Sixty-seven animals were rejected and sold. Nineteen young bulls were sold at their book values and three bulls were sold at the nominal prices of Rs. 100, 150 and 300 only.

* 11 died of infectious diseases.

† Mortality percentage due to ordinary ailments—8.8.

The annual statement of livestock is given below :—

Statement of livestock for the year 1938-39

Particulars	Balance on 1-7-38	Increase		Decrease			Balance on 30-6-39
		By transfer from other stock	By birth	By death	By Sale	By transfer to other stock	
Bulls	9	2	..	..	3	..	8
Cows	94	22	..	2	32	..	82
Young female stock	85	..	47	11	13	22	86
Young male stock .	60	..	42	16	19	12	55
Total	248	24	89	29	67	34	231

3. STATISTICAL BRANCH

(P. V. KRISHNA IYER)

I. REVIEW OF THE PERMANENT MANURIAL EXPERIMENTS AT PUSA FROM 1930-38*

The accompanying Tables I and II give in brief the position of the permanent manurial experiments at Pusa since 1930.

Effect of rotation on the yield of maize—Groups I and II.—Maize coming after peas was superior to that after barley, wheat or *rahar*. The yields after *rahar* from the farmyard manure and the rape cake plots were practically the same. From the nitrogen and the potash manured plots, the yield after *rahar* was less than that after wheat. When maize was preceded by wheat, the addition of 20 lb. N + 25 lb. K₂O + 40 lb. P₂O₅ per acre was not sufficient to give an outturn equivalent to that from the 4,000 lb. farmyard manure plot. After *rahar* and peas, the yield from the 20 lb. N + 25 lb. K₂O + 40 lb. P₂O₅ plot went up to the level of 4,000 lb. farmyard manure plot.

Relative values of different manures—Groups I and II.—The yields of maize show that 4,000 lb. farmyard manure + 20 lb. N as rape cake per acre was superior to the other manures. The application of 20 lb. N + 25 lb. K₂O + 40 lb. P₂O₅ failed to produce any response to the level of 4,000 lb. of farmyard manure per acre. Unlike the permanent manurial experiments of the old series (1909-1930), the yield of maize grown in conjunction with *rahar* after barley was the same as that grown alone after wheat or *rahar* from the farmyard manure and the rape cake plots. In the case of artificials, the yield of maize when grown in conjunction with *rahar* was far less than that when grown alone, preceded by peas, wheat or *rahar*.

For the *rabi* crops, the yield was more from the 8,000 lb. farmyard manure and the 4,000 lb. farmyard manure + 20 lb. N as rape cake plots. The residual effect of 40 lb. N as rape cake was at the most equal to that of 4,000 lb. of farmyard manure per acre. The yields of wheat, barley, peas and *rahar* from item 10 (complete artificials) were the same, if not more, than that from

* For details of this experiment *vide* report of the Imperial Agriculturist from 1930-36 and that of the Botanical Sub-station, Pusa, 1936-37 and 1937-38.

the farmyard manure plots. The application of superphosphate improved the yield to a considerable extent. In the case of *rahar*, the superphosphate manured plots yielded more than any of the other plots.

Group III—Examining the yields of the Group III series, we arrive at the following conclusions :—

- (a) Rotation followed in plot No. 14 was unsatisfactory.
 - (b) Manuring with green manure after peas was definitely better than that after *rahar*. The residual effect of green manure in *rabi* as reflected on peas and *rahar* was very small. As could be expected, there was some residual effect in *kharif* on the maize crop. But it was limited and small.
 - (c) The addition of superphosphate gave a very high outturn, more than double that of 8,000 lb. of farmyard manure. The residual effect on maize also was considerable. The yield was as high as that of the 8,000 lb. farmyard manure plot. The succeeding residual effect on peas and *rahar* also was marked.
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TABLE I
Permanent Manurial Experiment at Pusa, 1930-38—Groups I and II

Average yield of grain in lb. per acre

Manure	Maize after peas	Maize after wheat	Maize after <i>rahar</i>	Maize grown with <i>rahar</i> after barley	Wheat after maize	Barley after maize	Peas after maize	<i>Rahar</i> after maize
1. No manure	774.3 ± 109.56	644.0 ± 114.82	444.9 ± 75.88	473.5 ± 55.80	407.3 ± 58.35	396.2 ± 77.10	293.3 ± 50.03	591.9 ± 96.54
2. F. Y. M. 4,000 lb. per acre	1,272.7 ± 189.75	1,041.7 ± 175.40	1,037.3 ± 125.84	979.0 ± 142.27	785.5 ± 101.06	569.5 ± 133.55	568.3 ± 102.32	962.8 ± 167.22
3. F. Y. M. 8,000 lb. per acre	1,760.7	1,243.0	1,159.5	1,241.0	1,039.5	920.8	832.0	1,134.0
4. F. Y. M. 4,000 lb. + Rape cake 20 lb. N per acre.	1,784.0	1,383.0	1,403.3	1,523.3	948.8	989.0	737.0	939.8
5. Rape cake 40 lb. N per acre.	1,570.3	1,205.7	1,160.5	1,188.0	640.0	739.3	457.0	851.3
6. (NH ₄) ₂ SO ₄ 40 lb. N per acre.	770.7	548.0	411.3	335.8	382.0	494.8	252.5	719.5
7. K ₂ SO ₄ 50 lb. K ₂ O per acre	750.3	505.3	404.5	430.3	368.3	411.0	276.3	617.0
8. Super. 80 lb. P ₂ O ₅ per acre	1,041.7	561.0	805.3	520.0	777.0	852.0	775.8	1,278.5
9. K ₂ CO ₃ 50 lb. K ₂ O + Super. 80 lb. P ₂ O ₅ per acre	983.0	627.3	800.8	551.0	879.3	783.0	807.0	1,250.5
10. (NH ₄) ₂ SO ₄ 40 lb. N + K ₂ SO ₄ 50 lb. K ₂ O + Super. 80 lb. P ₂ O ₅ per acre	1,093.0	785.7	1,143.3	820.3	989.5	1,126.8	773.8	1,279.5
11. (NH ₄) ₂ SO ₄ 40 lb. N + Super. 80 lb. P ₂ O ₅ per acre	608.7	655.3	993.3	468.3 ± 164.29	846.0	693.5	828.8	1,512.0
12. (NH ₄) ₂ SO ₄ 40 lb. N + K ₂ SO ₄ 50 lb. K ₂ O per acre	741.3	683.0 ± 214.82	342.5	356.5 ± 142.27	399.5	613.0	191.5 ± 144.71	473.3

NOTE:—Organic manures were applied in one dose while the artificals were applied half in *kharif* and half at the time of *rabi* sowing.

TABLE II
Permanent Manurial Experiments at Pusa, 1930-38—Group III

Average yield of grain in lb. per acre

Description of manure	Maize after a cereal crop with G. M.	Wheat after G. M.	Barley after G. M.	Peas (Residual effect of G. M.)	Rahar (Residual effect of G. M.)
Plot No. 14—					
G. M. with cereal rotation . . .	...	540.8±23.26	644.13±55.29	...	...
Plot No. 15—					
G. M. followed by a leguminous crop . . .	880.9±138.41	741.3±80.19 (Preceded by rahar).	1118.3±97.29 (Preceded by peas).	296.0±69.20	481.8±100.85
Plot No. 16—					
As in plot No. 15 + 80 lb. P ₂ O ₅ per acre . . .	1245.6±45.02	1818.3±123.19 (Preceded by rahar).	2379.0±279.35 (Preceded by peas).	937.7±75.75	958.0±166.85

II. INVESTIGATIONS

1. RELATIVE USEFULNESS OF LATIN SQUARE AND RANDOMISED BLOCK LAY-OUTS

A large number of Latin square and randomised block experiments was conducted at Pusa before the transfer of the Institute to Delhi. An examination of these experiments would give us some information as to which of the lay-outs is preferable in actual practice.

Defining the efficiency of a lay-out to be the ratio of the variances after replacing the actual treatments by dummy treatments on the basis of complete and restricted randomisation, we find that the efficiency factor for randomised block and Latin square experiments are—

$$\frac{Bb + Et + Ee}{E(b + t + e)} \quad \text{and} \quad \frac{Rr + Cc + Et + Ee}{E(r + c + t + e)}$$

respectively, where B, T, E and b, t, e are the respective variances and the degrees of freedom for blocks, treatments and error in the case of randomised block lay-outs and R, C, T, E and r, c, t, e are the respective variances and the degrees of freedom for rows, columns, treatments and error for Latin square lay-outs. The table below gives the efficiencies of some of the experiments carried out at Pusa on the basis of the above formulae.

Description	Latin square		Randomised blocks		
	Efficiency on the basis of complete randomisation	Number available	Number of blocks	Efficiency of the basis of complete randomisation	Number available
*4 (3 × 3) . . .	6.60	9	3	1.01	1 (complex expts.)
(4 × 4) . . .	3.31	9	4	1.56	1
2(4 × 4) . . .	4.27	16	6	1.53	35
(5 × 5) . . .	3.57	3	7	1.20	1
2(5 × 5) . . .	2.72	2	8 & more	1.70	14
(6 × 6) . . .	1.91	4			
(7 × 7) . . .	1.54	2			
(8 × 8) . . .	2.47	11			
(11 × 11) . . .	1.57	3			
General average . . .	3.66	59	General average	1.56	52

*4 (3 × 3) means that the experiment consisted of four (3 × 3) Latin squares.

The above table clearly indicates that the Latin square lay-outs are superior to the randomised blocks. Thus the facts borne out by actual field experiments are in accordance with theoretical expectations.

2. UNIFORMITY TRIAL WITH WHEAT

In the year 1936-37, a uniformity trial was conducted at Karnal with Pusa wheat 114 on an area of 1.1478 acres ($125' \times 400'$). At the time of harvest the whole area was divided into two thousand plots of $5' \times 5'$, and the yield for all the plots was noted in ounces. There were twenty-five rows and eighty columns in all.

Distribution of plot yields.—Constants β_1 , β_2 and χ^2 for measuring the deviations from a normal curve for a few plot sizes are given below :—

Description of plot, size and area taken	β_1	β_2	χ^2
($5' \times 5'$) 25 rows $\times$ 1-20 columns . .	0.186	2.805	44.4 P < .01
($5' \times 5'$) 25 rows $\times$ 21-60 columns . .	0.228	3.361	45.8 P < .01
($5' \times 5'$) 25 rows $\times$ 61-80 columns . .	0.057	3.485	31.0 P < .01
($10' \times 5'$) 25 rows $\times$ 1-20 columns . .	0.169	2.461	19.1 P < .05
($10' \times 5'$) 25 rows $\times$ 21-40 columns . .	0.023	2.580	13.0 P > .20
($10' \times 5'$) 25 rows $\times$ 41-60 columns . .	0.162	2.859	17.7 P < .05
($10' \times 5'$) 25 rows $\times$ 61-80 columns . .	0.004	3.339	9.3 P > .68
($10' \times 10'$) 25 rows $\times$ 1-20 columns . .	0.061	1.980	Not calculated
($10' \times 10'$) 25 rows $\times$ 21-40 columns . .	0.197	2.544	Do.
($10' \times 10'$) 25 rows $\times$ 41-60 columns . .	0.099	2.536	28.4 P < .05
($10' \times 10'$) 25 rows $\times$ 61-80 columns . .	0.000	2.496	11.1 P > .70

The above table shows that the distribution of the yields from the ultimate plot-sizes was far from normal. The distribution for larger plot-sizes had a tendency to become not far from the normal curve.

Size and shape of plots for wheat experiments.—The coefficient of variation for a large number of plot-sizes after making allowance for block effects on the basis of five dummy treatments in each block was calculated for blocks running along rows as well as columns and the results are summarised below :—

(a) *Blocks running along rows.*—For areas lying between 75 sq. ft. and 150 sq. ft., the coefficient of variation was between eleven and nine. When the area was between 150 sq. ft. and 500 sq. ft. the value of the coefficient of variation was between six and nine.

(b) *Blocks running along columns.*—In this case also the coefficient of variation for areas between 75 sq. ft. and 150 sq. ft. lay between 10 and 11.5. For greater areas up to 525 sq. ft. the coefficient of variation was between eight and ten. In both the cases cited above a further increase in area did not result in any substantial reduction in the value of the coefficient of variation.

As regards the shape of plots, rectangles having the ratio of their length to breadth lying somewhere between 3 and 5 and the blocks running counter to the length of plots appeared to be the best for experimental purposes.

Latin square versus randomised blocks and plot-size

In eleven cases the effect of assuming the experiment to be a 5×5 Latin square in place of randomised block of five plots was worked out and the results are tabulated below :—

Plot size	Area in sq. ft.	C. V. before elimination	C. V. after elimination	% Efficiency
5' × 5'	25	18.3	11.6	250
5' × 10'	50	16.0	9.3	298
10' × 5'	50	15.1	9.1	275
5' × 15'	75	15.2	8.6	317
15' × 5'	75	12.9	7.0	336
20' × 5'	100	13.6	7.1	364
5' × 20'	100	14.0	7.4	359
10' × 10'	100	13.6	8.6	251
25' × 5'	125	13.5	8.6	250
20' × 10'	200	12.4	6.6	349
15' × 15'	225	13.5	7.9	297

The efficiency of Latin squares was far more than that of randomised blocks. In the majority of cases, the efficiency of randomised blocks was less than two hundred. The reduction of the coefficient of variation was rapid up to 75 sq. feet, after which it was more or less stationary.

Relation between variances after elimination for block effects and area of plots

A curve represented by the equation

$$\log y = \frac{A}{x^2} + \frac{B}{x} + C$$

(y and x being variance after elimination and area in sq. feet respectively) has been found to fit satisfactorily with the variances calculated for blocks running along rows. The actual equation obtained was

$$\log y = \frac{5371.7}{x^2} + \frac{285.6}{x} + 4.078$$

The analysis of variance given below shows that the fit could be considered satisfactory.

Analysis of variance for log y

Variance due to	d. f.	s. s.	m. s.	s^2_1/s^2_2
Fitting constants	2	32.11	16.055	111.7
Deviation from the curve	48	6.90	0.144	

Number of treatments per block

The percentage efficiency for block containing 5, 7, 8, 10, 11, 13, 15, 16 and 20 treatments for different plot sizes is given in the accompanying table.

% Relative efficiency for different block sizes—blocks running along rows

Area Rows and Columns	Number of treatments per block										Rel. eff. = V. before eli. — V. after eli. × 100.
	5	7	8	10	11	13	15	16	20		
25' × 20'	239.43	200.19	178.19	121.72	156.93	115.67	147.82	149.60	109.48		
30' × 20'	241.39	241.39	203.27	127.14	190.02	167.74	176.80	177.78	117.27		
25' × 25'	147.14	130.90	122.12	148.53	142.63	149.31	114.29	109.61	...		
35' × 20'	285.36	335.34	249.49	129.97	221.25	183.64	194.52	196.94	121.63		
30' × 25'	165.90	141.26	128.26	174.81	171.61	179.39	126.17	118.71	...		
35' × 25'	189.83	151.32	131.00	189.87	184.83	194.04	130.29	122.92	...		
40' × 25'	176.41	146.76	136.59	168.84	165.79	171.84	130.92	124.39	...		
30' × 35'	136.12	178.76	173.80	140.60	120.43	...	...	...	...		
45' × 30'	147.69	111.01	97.97	94.75	95.63	96.96	120.22	114.84	...		
60' × 25'	153.82	122.07	112.56	159.80	174.16	173.42	...	...	...		

The table shows that the efficiency is fairly high for blocks containing thirteen plots.

3. SAMPLING EXPERIMENTS ON SUGARCANE

At Karnal the Second Entomologist had two sets of experiments on a randomised basis with ten replications of 1/20 acre, each having 15 rows of cane 95 feet long and 18 inches apart under four varieties of cane, *viz.*, Co. 285, Co. 312, Co. 313 and Co. 331. One of the sets was devoted for fortnightly examination of canes from the point of view of insect attack by digging out all the canes from a certain length. The other set was intended only for making observations at the time of harvest.

At the time of harvest, samples for determining (i) the percentage attack by insects and (ii) the loss in weight caused by various insects were taken from both sets for the different replications by two methods. The first method of sampling consisted in selecting from every replication a certain length of cane from rows taken at random so as to give about hundred canes (15 feet for Co. 285 and 30 feet for the other varieties). The other method was by taking about hundred canes for every replication from clumps chosen at random from the whole plot. The difference between the two methods lay in the fact that while in one, the whole sample was confined to a portion of a row selected at random, in the other it was taken on clump basis from the whole plot.

The data were collected by the Second Entomologist under my instructions. Further details of the experiment can be had from his report for the year 1938-39.

The statistical aspects of the results obtained by the two methods of sampling are discussed below :—

Average percentage of canes attacked by different pests

Set I. Periodical observations

Pests	Variety	Healthy		<i>Scirpophaga nivella</i> F.		<i>Emmalocera depressella</i> Swinh.		<i>S. nivella</i> F. and <i>E. depressella</i> Swinh.		Termites	
		1st Method	2nd Method	1st Method	2nd Method	1st Method	2nd Method	1st Method	2nd Method	1st Method	2nd Method
Co. 285.	.	.	.	15.48	13.70	22.53	5.33	7.96	0.96	1.56	
Co. 312.	.	52.23	46.75	23.33	20.73	15.02	11.28	11.25	0.97	1.86	
Co. 313.	.	40.39	40.86	15.93	12.68	27.22	10.28	9.90	1.08	1.61	
Co. 331.	.	44.08	37.22	9.87	17.39	30.32	4.73	7.03	1.49	2.13	
S. E. of Mean	.	51.22	45.44	1.85	1.69	2.21	1.31	1.14	0.44	0.51	
Residual Variance	.	2.45	2.27	18.33	28.69	48.98	17.17	13.05	1.90	2.58	
		60.18	51.37								
Set II. Final Observation Plots											
Co. 285.	.	.	.	8.38	12.34	37.28	7.56	9.29	0.85	2.70	
Co. 312.	.	43.70	42.02	21.69	21.64	29.32	15.41	16.28	1.01	3.22	
Co. 313.	.	26.51	27.71	14.08	14.71	37.28	13.22	12.48	1.93	1.22	
Co. 331.	.	29.21	38.30	7.24	10.59	37.28	11.15	13.61	2.77	2.11	
S. E. of Mean	.	38.04	35.71	1.52	1.85	3.16	1.56	1.39	0.75	0.89	
Residual Variance	.	3.59	2.47	23.13	34.08	100.07	24.41	19.43	5.55	7.93	
		129.05	60.83								

The two tables shown above give the means, the standard errors and the residual variances of (i) weight of healthy and pest affected canes and (ii) the percentage of canes attacked by various pests for the two methods of sampling.

One might easily be led to think that the second method is more representative than the first one. But an examination of the two tables shows that the means and the variances are practically the same for both the methods. In almost all cases, the differences between the means and the variances of the two methods can be accounted for by errors due to sampling. Hence we find that both the methods of sampling are equally effective. Therefore for the purpose of sampling sugarcane, any of the two methods outlined above can be adopted—the second one appears to be more convenient from the practical point of view.

4. ANALYSIS OF ASYMMETRICAL EXPERIMENTS

A detailed investigation on the analysis of asymmetrical experiments with special reference to the partition of the sum of squares for treatments was made for simple and complex experiments by successive application of the principle of least squares.

REPORT OF THE IMPERIAL ECONOMIC BOTANIST

(B. P. PAL)

I. INTRODUCTION

Progress was made in the breeding of varieties of crops possessing disease resistance and other desirable qualities. The policy of laying increasing stress on genetical and cytogenetical studies and on problems of fundamental interest has been continued, and preliminary results of interest and value have been obtained.

The following sub-stations, financed by the Imperial Council of Agricultural Research, are under the control of this Section :—

- (i) Botanical Sub-station, Pusa.
- (ii) Potato and Wheat Breeding Sub-station, Simla.
- (iii) Tobacco Research Sub-station, Guntur.

The work done at these Sub-stations during the year under review is given in detail in the respective reports on these Sub-stations submitted separately to the Imperial Council of Agricultural Research. The salient features of the experimental work done at the Sub-stations are given under the appropriate subheads in the present report.

As in previous years a large number of enquiries were received from correspondents regarding varieties, methods of cultivation, curing, etc., and the information desired was supplied.

II. RESEARCH

I. BREEDING FOR DISEASE RESISTANCE

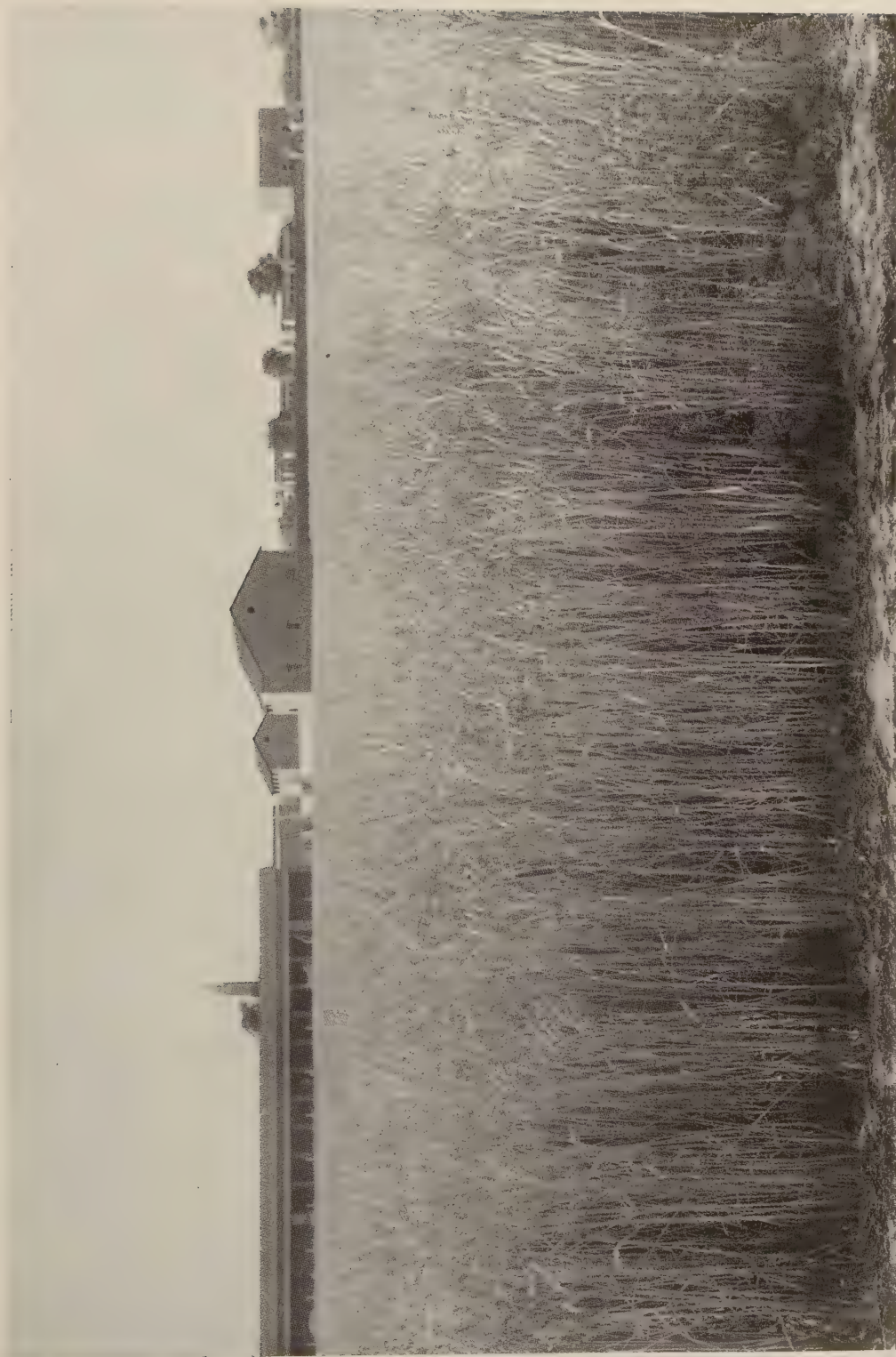
WHEAT (*Triticum vulgare* Host)

Rust resistance.—Breeding for rust resistance was carried out at the Sub-station at Simla with the co-operation of Professor K. C. Mehta. The F_4 generations of nine crosses were grown. Out of 2,640 seedlings tested 1,702 proved to be resistant. Plants were selected for growing the F_5 generation, on the basis of rust resistance and other desirable characters. In the cross between Reliance (*T. vulgare*) and Khapli (*T. dicoccum*) all the plants were of the Khapli type and thus of little agronomic value.

The F_1 populations of seven crosses made in the previous years were tested for reaction to black rust. Susceptibility was found to be dominant in all cases.

The study of a large collection of foreign and indigenous wheats (including hill wheats) with the object of discovering resistant forms suitable for use in breeding was continued. A promising degree of resistance to black rust has been found in some *vulgare* varieties from Kenya.

Smut resistance.—Co-operative experiments were carried out with the Mycological Section to test the resistance or susceptibility of a large number



An acre plot of Pusa 165 wheat which yielded over 40 maunds per acre.

of wheat varieties to loose smut and flag smut. A more detailed reference to these experiments will be found in the report of the Imperial Mycologist.

OATS (*Avena sterilis* L. var. *culta* and *Avena* spp.)

Smut resistance.—The study of the resistance of the Pusa oats and of some acclimatised exotic strains to covered smut (*Ustilago Kolleri* Wille) was continued in collaboration with the Mycological Section, New Delhi. The results are described in the report of the Imperial Mycologist.

POTATOES (*Solanum tuberosum* L. and *Solanum* spp.)

The most pressing problem of potato production in India is that of the numerous diseases which attack the plant in the field and the tubers in storage. Because of this, improvement of the potato largely means the breeding of disease-resistant varieties. The work is being conducted partly at Delhi and partly at the Potato Breeding Sub-station at Simla. Some stocks were also grown at the Botanical Sub-station at Pusa.

Among the most serious diseases of the crop are Late Blight, Early Blight and virus diseases such as mosaic and leaf-roll. Work on Late Blight has been in progress for several seasons, depending upon natural epidemics for the selection of resistant plants, and was continued during the year under review. Late Blight appeared in the end of August and the attack was mild. Further selections were made in the progenies of crosses involving *Solanum demissum* or *S. Antipoviczii* as the resistant parent. Work was continued also in the crosses between *S. andigenum* and *tuberosum* varieties such as Pusa White, Katahdin, etc.

Field observations on the incidence of Early Blight and virus diseases were continued. The construction of an insect-proof glass house at the Simla Sub-station having been completed, disease-free foundation stocks of a number of important commercial potato varieties are being maintained.

LINSEED (*Linum usitatissimum* L.)

Rust resistance.—One hundred and fifty F₅ cultures of crosses between Pusa strains which are susceptible to rust, (*Melampsora lini*) and resistant exotic varieties were grown at Delhi and Pusa, together with the parents for study of rust resistance. At Delhi, the disease was practically absent and hence a comparative estimate of the disease resistance of the different selections could not be made. At Pusa, however, there was a heavy incidence of rust and an examination of the cultures showed that about 78 per cent of them were absolutely free from rust, 19 per cent had only traces, 2 per cent had moderate rust and 1 per cent had severe rust. The parents remained constant as regards reaction to rust, the Pusa strains being very susceptible and the exotic types immune to the disease. Desirable single plants with a high degree of resistance were selected for further trial.

PIGEON-PEA [*Cajanus Cajan* (L.) Millsp.]

A wilt-resistant pigeon-pea strain was isolated from Type 69 at the Botanical Sub-station, Pusa. This resistant strain will be re-tested under severe conditions of soil-infestation, in collaboration with the Imperial Mycologist.

2. BREEDING FOR OTHER CHARACTERS

WHEAT

Non-shedding strains.—Selections were made from progenies of variants in Pusa 114 and Pusa 120 with a view to eliminate the defect of grain shedding in these otherwise valuable strains. In preliminary yield tests during the year, one of the selections from Pusa 120 has out-yielded the latter by about two and a half maunds per acre in bulk plots. Further trials with these selections will be continued.

Drought resistance.—In order to test the suitability of the Pusa wheat for cultivation under dry conditions, small plots of nine varieties were grown absolutely without irrigation. The germination was poor in all cases due to lack of soil moisture. It is intended to grow a larger number of varieties next season with the object of discovering drought resistant varieties.

TOBACCO (*Nicotiana Tabacum* L. and *N. rustica* L.)

High yield and nicotine content.—*N. rustica* with a higher nicotine content than *N. tabacum* is at present exclusively used for *hooka* smoking and snuff making. Any improved strain of this tobacco which may be bred for high yield and nicotine content can also be utilized for the manufacture of commercial nicotine sulphate, which is in demand as an insecticide. With a view to evolve types that will be useful for this dual purpose, a large number of indigenous and exotic varieties were under study at Delhi. Leaves from twenty plants of each type have been sun-cured for estimation of yield and nicotine content. There are indications that certain of the varieties may prove to be superior to those at present under cultivation in point of yield and nicotine content.

A number of crosses for the study of inheritance of nicotine content and leaf characters were made during the year.

HIBISCUS (*Hibiscus cannabinus* L.)

Early maturing strains.—Breeding work for the evolution of early maturing strains of *Hibiscus cannabinus* was continued. Hybrid progenies of crosses between Type 6, and early maturing exotic varieties were studied and selections of plants with desirable characters were made.

3. GENETICAL AND CYTOLOGICAL STUDIES

Experiments to induce chromosome doubling in plants by the use of colchicine

The discovery of colchicine as an effective agent for doubling chromosomes in plants has placed an important tool in the hands of the breeder for producing polyploids. During the year under report experiments were in progress to induce chromosome doubling in chillies, gram and tobacco and the results are summarised below :

CHILLIES (*Capsicum annum* L.)

Seeds were immersed in colchicine solutions of 0.05 per cent to 0.4 per cent for varying periods (1-8 days) and later on planted out in the field. Out

of 242 plants, 77 turned out to be tetraploids; the largest number of tetraploids (57 per cent) being obtained from seeds treated with 0.2 per cent solution. Apart from tetraploids, one triploid and a few pollen lethal mutations without change in the chromosome number, were also identified among treated plants. The tetraploids were slow-growing with broad, succulent leaves, large size of pollen and reduced seed-setting as compared to the diploids. The tetraploid plants were studied cytologically and seeds collected from them for further study.

GRAM (*Cicer arietinum* L.)

Sprouted seeds of Type 20 were immersed in colchicine solutions of different strengths (0.25 per cent to 1.0 per cent) for different lengths of time (1/2 hour to 24 hours) and then planted out in pots. The seeds treated with weaker concentrations for short periods showed a decided thickening of the root tips 24 hours after treatment, while those immersed in higher concentrations and for longer periods showed a shrivelling and browning of the tips after the same interval following the treatment. From 120 treated seeds, only 25 plants were obtained of which 12 proved to be tetraploids on cytological examination. There was one plant which had leaves with stomata of the octoploid type but its flowers were tetraploid. The tetraploids, as expected, showed increased vigour with larger leaflets and flowers. Seed setting was variable and generally less than in the diploids. Seeds from these plants have been collected for growing a further generation.

TOBACCO

The two interspecific sterile hybrids viz. *N. Tabacum* ($2n=48$) $\times$ *N. plumbaginifolia* ($2n=20$) and *N. glauca* ($2n=24$) $\times$ *N. plumbaginifolia* ($2n=20$) which were successfully made for the first time three years ago and since then propagated vegetatively, were studied cytologically. The former hybrid showed varying numbers of bivalents and univalents in pollen mother cells at meiosis, while the latter showed practically all univalents except for occasional bivalents. The meiosis was abnormal in both cases and the pollen sterile. The plants did not set seed for the last three years either in open pollination or in backcrosses. With a view to make these plants fertile, attempts were made to induce chromosome doubling in them. Treating the growing buds with different strengths of colchicine solution and emulsions of colchicine solution in lanolin has so far been unsuccessful. The treated buds developed leaves with characteristic roughness and fasciation and even increased stomatal size but later on produced flowers which were as sterile as those on untreated branches. Cytological examination of pollen meiosis in the flowers showed no change in the chromosome number. Further experiments are under way.

Experiments to induce mutations by means of X-rays

The use of X-rays for production of mutations in plants is well known. Preliminary experiments were undertaken during the year to induce mutations in tobacco and *Brassica*. Wet and dry seeds were exposed to X-rays under a Coolidge bulb operated at 52 k.v. power with a tube current of 5 m.a. and a target distance of 20 cm. for 20 minutes in each case. The X-raying was done at the Irwin Hospital, Delhi, by the courtesy of the Radiologist of the

Hospital. The seeds after treatment were sown in boxes and the seedlings planted out in the field. Examination of the adult plants showed no visible difference between the treated and control plants. Seeds from some of the treated plants have been collected for sowing next year.

The experiment will be repeated with suitable modifications.

Cytogenetical Study of the Oleiferous Brassicæ

Work on this group of plants which includes *sarson* (*Brassica campestris* var. *sarson*), *toria* (*B. napus* var. *dichotoma*), *rai* (*B. juncea*) and also *taramira* (*Eruca sativa*) was expanded to include cytological investigations with a view to the elucidation of their interrelationships and classification. The study of self-sterility was continued and a number of new mutations were isolated. A brief summary of the work done is given below.

(i) CHROMOSOME NUMBERS ; INTERSPECIFIC AND INTERGENERIC CROSSES

The chromosome numbers of representative types of the different cultivated *Brassicæ* in our collection were determined as follows :

Rai (*B. juncea*) $2n=36$, *sarson* (*B. campestris* var. *sarson*) $2n=20$, *toria* (*B. napus* var. *dichotoma*) $2n=20$, *Benarsi rai* (*B. nigra*) $2n=16$. *Taramira* (*Eruca sativa*) $2n=22$.

A number of wild relatives of the *Brassicæ* growing in the Botanical Area were identified and their chromosome numbers ascertained. Their basic numbers fall into an aneuploid series with 8, 10, 14 and 24 chromosomes which is a characteristic of the family *Cruciferae* to which the cultivated mustards belong. The usefulness of these plants for breeding will be tested. Reciprocal crosses between the different species of *Brassica* in all possible combinations were made for cytogenetical investigations leading up to the elucidation of their relationships and phylogeny. A number of intergeneric crosses were also made during the year.

(ii) STUDY OF SELF STERILITY

Group crosses to ascertain the mode of inheritance of self sterility in *toria* and *Benarsi rai* were made. Ten plants in the former and eight in the latter were crossed among themselves reciprocally in all possible ways and the crossed seeds were carefully collected. An examination of seed setting in the crosses indicates that the genetics of self sterility in these *Brassicæ* is rather complicated, owing presumably to their polyploid nature. The study will be continued next year.

(iii) MUTATIONS

During the year under report, a number of new mutations were isolated and were under study. A triploid ($2n=30$) in *toria* and haploid ($2n=18$) in *rai* were discovered for the first time and studied cytologically. At pollen meiosis, the triploid showed varying numbers of trivalents, bivalents and univalents in pollen mother cells while the haploid showed a few bivalents and univalents. The triploid was fairly fertile and is expected to give rise

to progeny with varying chromosome numbers. The haploid was almost completely sterile but its cytological behaviour is expected to throw considerable light on the origin of *B. juncea*. Three genic mutants were also isolated, viz., a male sterile mutant in *taramira*, an abnormal mutant which does not open its petals in *toria* and an interesting mutant without petals (apetalous) in *sarson*. Crosses between these mutants and their corresponding normal plants were made to study their inheritance. The apetalous mutant, is self fertile and the closed petal mutant is self sterile. These two mutant characters are likely to be economically useful if they could be bred into self fertile improved strains, as they would help to keep down natural cross pollination to a considerable extent and save the strains from deterioration.

Cytological study of a sterile mutant in chillies

A highly sterile chilli plant occurring in one of the cultures was examined cytologically and the cause of sterility was found to be due to non-pairing (asynapsis) of the chromosomes at meiosis. The plant set a few seeds under open pollination. Further study of this mutant and its progeny will be continued.

Genetical study of gram

The breeding behaviour of the two gram mutants, viz., the tiny leaved mutant and the simple leaved mutant, was studied in selfed and cross progenies. While the data obtained with the former mutant have shown it to be a simple recessive to the normal, those obtained with the latter are more complicated indicating a frequent reversibility of the mutant character in the course of breeding. This point will be confirmed in future work.

Several crosses between gram types were made during the year with a view to study the genetics of the species (*C. arietinum*).

Other genetical studies

Safflower (*Carthamus* spp.).—Two F_1 progenies of crosses between *C. tinctorius* $\times$ *C. oxyacantha* were under study. The spiny nature of the wild species and its grey seed colour were found to be dominant to spinelessness and white seed colour of the cultivated type.

Chillies.—The genetics of a variegated chilli plant occurring in one of the cultures was studied. The plant bore variegated (yellow and green) branches on one side and normal green branches on the other. The selfed progenies from the green branches were all green while those from the variegated branches turned out to be seedling lethals. The seedlings at first were normal with green cotyledons but soon died following a change in colour of the cotyledons to yellow. The progenies of reciprocal crosses were however green which indicates that the variegated character is a mendelian recessive to green. Further work is in progress.

Rice (*Oryza sativa* L.).—The study of inheritance of a finely variegated type was continued. The variegated plants give rise to variegated plants and albinos in successive generations. An occasional gave plant found in the progeny of a variegated plant, however, gave greens and variegated plants in the ratio of 3 : 1 approximately. So it is possible that while

the variegation behaves as a mendelian recessive to green, albinism is transmitted only maternally. Artificial crosses to confirm this tentative conclusion will be made during the coming year.

Maize (Zea Mays L.).—Genetical studies on maize were terminated as the assistant who had specialised in this crop left the Section.

Hybrid Vigour

Last year an account was given of a study of hybrid vigour in wheat. In order to discover suitable material for further studies on the subject and also to investigate the possibilities of its economic exploitation, preliminary observations of hybrid vigour were made on the F_1 generations of crosses in chillies, gram, maize and tobacco. Evidence of hybrid vigour in respect of certain characters was obtained and the work will be continued more intensively next year.

4. PHYSIOLOGICAL STUDIES

VERNALIZATION

Gram.—Seeds of four varieties of gram were vernalized (chilled) and grown under (1) natural conditions and (2) under different photoperiods, viz. 6-7 hours day light (short day condition), full day light (natural day) and 15-17 hours light (long day), the daylight in this case having been supplemented by electric illumination. In the first experiment, the plants from treated seeds started initiation of the flower buds fifteen days earlier than the control plants and maintained this difference through subsequent phases of development, up to maturity. In the second experiment, the control and treated plants grown under long day conditions flowered almost simultaneously but earlier than the others in the series.

Wheat.—Three English wheats (Cambridge Rivett, Yeoman II and Joss 4) and two Indian wheats (Pusa 114 and Pusa 165) were studied on similar lines to gram. Under natural conditions, plants from treated seeds of Cambridge Rivett flowered five days earlier than the controls but those from the Indian wheats flowered almost simultaneously with their corresponding control plants. The response of these plants to light has, however, been interesting. Plants from chilled seeds of Cambridge Rivett flowered 9 weeks earlier under "long days" than those under "natural days", which in turn flowered earlier than those under "short days". Unchilled seeds of the same variety did not show the same acceleration in development under "long days". Plants from unchilled seeds of the Indian wheats, Pusa 114, however, flowered earlier under "long day" conditions. Further experiments with wheat and other crops are being continued.

SHORTENING THE REST PERIOD OF THE POTATO

The results of experiments on shortening the rest period of potato tubers which had been carried out for two years at Pusa prior to the transfer of the Institute to Delhi were analysed. The most successful treatment was peeling the tubers and storing them in moist sawdust for a week; the response to this

treatment was the quickest and also the most uniform. Treatments in which tubers were exposed to ethylene chlorhydrin were also successful. While it is unlikely that any of these methods will at present be adopted by commercial growers, they may however be of value to potato breeders and geneticists.

During the year under report a new series of experiments were carried out, the treatments employed being exposure for varying periods to carbon bisulphide vapour and also to smoke. None of these treatments was successful in abbreviating the rest period of the tubers.

5. VARIETAL STUDIES

An important item of the work of the Section is the collection and maintenance of material for breeding purposes. In the case of some crops the available material has been studied and described in the past. In other cases the studies are still in progress and short notes on these are given below. An account is also given of the results of the study of the Indian peas material which has been completed.

PEAS

Peas are extensively cultivated in certain parts of India during the cold weather for food as well as for fodder. The crop is of considerable importance in the United Provinces, Bihar, Orissa, Bengal, Central Provinces, and some tracts of the Punjab and Bombay. The isolation of pure types of peas cultivated in India, was, therefore, undertaken some years back at Pusa. Forty-one types of *Pisum sativum* L. and thirty types of *P. arvense* L. were isolated from the seed samples obtained from different parts of India. These types have now been classified and described. The following major differences were observed between *P. arvense* and *P. sativum* :—

Characters	<i>P. sativum</i>	<i>P. arvense</i>
Flower colour . . .	Flowers white . . .	Flowers coloured.
Seed-coat colour . . .	White, rarely showing brown marbling.	Some shade of green, generally with some pattern, violet spotting or brown marbling, or both kinds of markings.
Hilum colour . . .	Generally white, sometimes black.	Generally brown sometimes black.
Cotyledon colour . . .	Green or yellow . . .	Yellow.
Leaf-axil, pod colour, etc. .	Green . . .	Margin of leaf purple, leaf-axil sometimes green, but generally purplish red. Some purple colour present on the suture or on the sides of pods.
Size characters . . .		Seeds, flowers, pods and leaves are generally smaller.

The characters that have been found useful for the classification of the types are :—

Seed characters

1. *Seed-coat colour*.—The testa may be white as in *P. sativum* or some shade of green as in *P. arvense*. There are two patterns on the testa, violet spotting and brown marbling which may occur separately or together.
2. *Hilum colour*.—White, brown or black.
3. *Seed surface*.—Smooth, wrinkled or indented.
4. *Colour of cotyledons*.—Green or yellow.
5. *Seed size*.—The weight of seeds is not a true index of seed size in peas particularly in the wrinkled seeds which though large, are not correspondingly heavy in weight. Some grades can however be recognised by eye judgement.

Flower characters

6. *Flower colour*.—White, pink or purple. In the white group a few types have wings with pink margins.
7. *Shape of standard*.—This depends upon the curvature of its sides which may (a) curve downwards before rising up, or, (c) may rise up rather abruptly, or, (b) take an intermediate position between these two.

Pod characters

8. *Texture of pod*.—Parchmented, when a lining is present inside the pod ; sugary, when such lining is absent or insignificant.
9. *Pod apex*.—Blunt or acute. It should be judged when the mature pod is full of grains.
10. *Shape of pod*—
 - (1) Straight or practically straight.
 - (2) Curved.
11. *Pod size*.—The length of the pods in the different types was found to vary from 4.5 to 11.5 cm. and breadth varied from 0.7 to 2.2 cm. Pods up to 6 cm. in length have been taken as short, 6-9 cm. as medium in length and above 9 cm. as long. Similarly the pods have been called narrow up to 1.4 cm. breadth and broad above this limit.

Other characters

12. *Leaf-axil colour*.—Green or purplish red.
13. *Plant height*—

Dwarf up to 120 cm.
Medium 121-190 cm.
Tall 191-260 cm.

14. *Maturity*.—Three classes have been made, early, medium, and late, according to the date of flowering. The commencement of westerly hot winds at the ripening period often makes classification based on ripening period difficult.

The types have been grouped as follows :—

Flowers white (*P. sativum*)

Margin of the wings white—

Pods sugary Types 1 and 2

Pods parchmented—

Seed-coat white having no marking—

Hilum black Types 3-5

Hilum white—

Seed surface smooth—

Shape of standard "a" Types 6-8

Shape of standard "b"—

Seed small Types 9-15

Seed medium in size Types 16-19

Seed large Types 20 and 21

Shape of standard "c"—

Seed small Types 22 and 23

Seed large Types 24 and 25

Seed surface wrinkled—

Shape of standard "a" .

Pod apex acute Types 26-28

Pod apex blunt Types 29-31

Shape of standard "b"—

Pod apex acute Type 32

Pod apex blunt Types 33-36

Shape of standard "c" Type 37

Seed-coat white having brown marbling Types 38 and 39

Margin of the wings pink. Types 40 and 41

Flowers coloured (*P. arvense*)—

Flowers pink Type 1

Flowers purple—

Pods sugary Type 2

Pods parchmented—

Seed-coat not spotted—

Hilum black Types 3-5

Hilum brown Types 6-8

Seed-coat having violet spotting—

Hilum black Type 9

Hilum brown—			
Shape of standard "b"	.	.	Types 10 and 11
Shape of standard "c"	.	.	Types 12 and 13
Seed-coat having brown marbling—			
Hilum black	.	.	Type 14
Hilum brown	.	.	Types 15-18
Seed-coat having both violet spotting and brown marbling—			
Hilum black	.	.	Types 19 and 20
Hilum brown—			
Leaf-axil green—			
Shape of standard "b"	.	.	Types 21-24
Shape of standard "c"	.	.	Types 25 and 26
Leaf-axil purple—			
Shape of standard "b"	.	.	Types 27 and 28
Shape of standard "c"	.	.	Types 29 and 30

For the final discrimination into types the characters of shape and size of pod, seed size, stature and maturity, etc., have been used.

Observations on the biology of flowers show that the flower buds open completely between 11 A.M. and 5 P.M. in January. The flowers remain open for 2 to 5 days before they are finally closed. Self-pollination is the rule in peas but a little natural crossing is possible as a large number of bees visit the flowers and occasionally there may be some abnormal development of flower parts by which the stigma is exposed.

Potatoes

Great confusion has hitherto existed regarding the varieties of potatoes cultivated in India. One of the first steps which had therefore to be taken in connection with the work on the improvement of the potato in this country was the elucidation of the variety question. A study of an all-India collection of over 300 samples was undertaken and after two years' observations it was possible to eliminate many of the synonymous stocks and to place the remainder into a comparatively small number of groups. Samples of these were sent to England and identified through the kindness of Dr. R. N. Salaman, the Chairman of the Potato Synonym Committee of the National Institute of Agricultural Botany. The results indicate that the number of true varieties grown in India is comparatively few, especially in the plains, and that most of the commercially important varieties in the plains spring from old and today possibly unidentifiable varieties.

Wheat

The study of the large collection of Indian and foreign varieties was continued. Material of wheats from Afghanistan received from the German Expedition to that country was also under study with the object of discovering forms suitable for breeding purposes.

Other Crops

The living crop collections were maintained.

6. FIELD TRIALS AND MISCELLANEOUS FIELD EXPERIMENTS

POTATOES

Time of sowing.—In the absence of information as to the most suitable time for planting potatoes at Delhi, a preliminary experiment was carried out in which three varieties, Gola, Military and Phulwa, were sown in batches on five different dates at intervals of about a fortnight. In the case of the first two varieties the planting made on 30th September definitely gave the best results. In the case of Phulwa both the planting made on 30th September and that on 15th October gave very good results, the latter being slightly better. It was observed that the number of mosaic diseased plants in Phulwa was considerably less in the later plantings although the material planted was from the same stock as that used for the earlier plantings.

Yield trial.—A preliminary yield trial (randomised blocks with 6 replications) was carried out with ten varieties including certain foreign disease-resistant varieties. The order of merit as regards yield was : Rogue No. 238, Pusa white, Cult. 186, Imperia, Numbri, Ekishirazu, President, Special, Khabrar and Darjeeling Red. The tubers of Darjeeling Red were somewhat dormant and hence the germination of this variety was very irregular.

WHEAT

The co-operative yield trials of the Pusa wheats in the United Provinces and Punjab were continued. The results are being statistically analysed.

OTHER CROPS

Varietal and manurial trials with barley, oats, rice, etc., were carried out at Pusa and the results are given in the report of the Botanical Sub-station.

III. CROP OUTTURNS AND SEED DISTRIBUTION

The growth of crops was on the whole very satisfactory and in the case of cereals strikingly high yields were obtained. Taking into consideration only plots of not less than one acre in area, five Pusa wheats gave a yield of over 40 maunds per acre (Plate I) and barley Pusa Type 13 gave a yield of over 57 maunds per acre. These figures point to the high cropping capacity of the strains bred at this Institute.

The quality of the produce was excellent. In the case of wheat high bushel weights were obtained as shown below :—

Bushel weights of wheat varieties in 1938-39

Variety	Weight per bushel in lb.
Pusa 4	68·70
Pusa 12	64·80
Pusa 52	67·25
Pusa 80-5	69·70
Pusa 111	68·40
Pusa 114	65·15
Pusa 120	64·35
Pusa 125	64·05
Pusa 165	66·90

As usual, reports on the crops obtained from seeds supplied by the Section and its Sub-stations were called for from the growers, and tabulated and analysed. On the whole the results are encouraging, although indicating the desirability that each grower should first endeavour to find out by preliminary trials which of the several improved varieties available is most suitable for the conditions of his particular tract.

The crop outturns for the Botanical Area at New Delhi are given in the statement below :—

Statement showing the yield of crops in the Botanical Area at New Delhi in 1938-39

Crop	Variety	Plot No.	Area in acres	Outturn of grain			
				Actual		Per acre	
				In Mds.	in lb.	in Mds.	in lb.
Wheat	Pusa 4	20	1.0	41.1	3384.0	41.1	3384.0
	Pusa 12	40	1.0	43.6	3583.6	43.6	3583.6
	Pusa 52	43	0.5	12.8	1055.3	25.6	2110.6
	Pusa 80-5	39	1.0	42.9	3528.0	42.9	3528.0
	Pusa 101	42	0.5	15.8	1298.1	31.6	2596.2
	Pusa 111	43	0.5	14.1	1162.3	28.2	2324.6
	Pusa 114	42	0.5	13.9	1141.7	27.8	2283.4
	Pusa 120	41	1.0	32.4	2666.1	32.4	2666.1
	Pusa 125	21	1.0	41.2	3388.1	41.2	3388.1
	Pusa 165	22	1.0	42.2	3472.5	42.2	3472.5
	Pusa T. 13	23	1.0	57.3	4717.0	57.3	4717.0
	Pusa B. S. 1	51	0.5	21.8	1789.7	43.6	3579.4
Oats	Pusa B. S. 2	51	0.5	23.6	1944.0	47.2	3888.0
	Pusa Hyb. C.	52	0.5	18.0	1481.1	36.0	2962.2
	Pusa Hyb. J.	52	0.5	23.3	1919.3	46.6	3558.6
	Pusa T. 25	36	1.0	26.7	2194.9	26.7	2194.9
Gram	Pusa T. 25	37	1.0	20.4	1678.6	20.4	1678.6
	Pusa T. 25	49	0.8	16.4	1345.4	20.3	1681.8
	Pusa T. 53	8	1.0	6.8	557.5	6.8	557.5
	Pusa T. 53	9	1.0	9.3	761.1	761.1	761.1
	Pusa T. 58	32	1.3	15.7	1231.9	12.1	993.8
	Pusa T. 58	34	0.7	11.5	946.3	11.4	931.9
	Pusa T. 58	35	0.8	13.6	115.0	17.0	1393.8
	Pusa S. 29	3	1.0	21.5	1765.0	21.5	1765.0
	Pusa S. 29	10	1.0	29.2	2400.7	29.2	2400.7
	Pusa S. 29	11	1.0	25.5	2084.2	25.5	2084.2
Peas	Pusa S. 29	12	1.0	31.2	2567.4	31.2	2567.4
	Pusa S. 29	50	0.8	25.8	2123.6	32.3	2653.8

Seeds were supplied by the Section and the Botanical Sub-station, Pusa, to the Agricultural Section for multiplication, and also to a large number of agricultural officers and private individuals in India and abroad. The quantities of seeds distributed by the Section are shown below :—

Statement showing the quantities of pure seeds distributed from 1st July, 1938 to 30th June, 1939

Variety	Quantity in lbs.
Wheat—	
Pusa 4	3383·6
Pusa 12	3844·4
Pusa 52	84·5
Pusa 80-5	4189·6
Pusa 101	372·3
Pusa 111	1705·0
Pusa 114	611·1
Pusa 120	1607·8
Pusa 125	4181·3
Pusa 165	4097·0
Barley—	
Pusa T. 13	4207·9
Pusa T. 21	1645·7
Oats—	
Pusa B. S. 1	1354·6
Pusa B. S. 2	2167·1
Pusa Hyb. C.	1795·9
Pusa Hyb. J.	2291·6
Gram—	
Pusa T. 25	516·8
Pusa T. 53	411·4
Pusa T. 58	587·3
Peas—	
Pusa S. 29	2105·0
Lentil—	
Pusa T. 11	82·3
Pusa T. III-86	86·4

IV. PROGRAMME OF WORK FOR 1939-40

(i) Continuation of the breeding work paying special attention to disease resistance.

(ii) Continuation of the genetical and cytological studies mentioned in this report.

(iii) Continuation of the special studies on vernalisation and hybrid vigour.

(iv) Investigation of the factors influencing seed-setting in berseem.

(v) Continuation of varietal studies and maintenance of crop collections.

REPORT OF THE SUGARCANE EXPERT

(T. S. VENKATRAMAN)

I. INTRODUCTION

This report embodies work on breeding carried out at the sugarcane-breeding Section of the Imperial Agricultural Research Institute, New Delhi, and located at Coimbatore in South India. Salient results from the two schemes financed by the Imperial Council of Agricultural Research and run by this Station are included. These are (1) Scheme for research on the genetics of sugarcane, and (2) the Sugarcane Sub-station, Karnal, in the Punjab. Breeding with special reference to the thick or tropical types is described in section V.

Starting of a liaison with the research section of the Madras University deserves to be mentioned. With the sanction of Government to meet comparatively small amounts of travelling expenses, Dr. T. Ekambaram of the Presidency College at Madras deputed one of the University research students to work out the external and internal morphological characters of the sugarcane bamboo hybrids. Some valuable results have resulted from this work and bearing on the inheritance of anatomical characters—a somewhat recent development in inheritance studies. The Station has gained from the wider and more academic outlook brought to bear on this investigation, and the Research Section of the University received both facilities and material in an interesting piece of research work.

II. SUGARCANE BREEDING

1. SUGARCANE BAMBOO HYBRIDS

Trigeneric and other hybrids.—Sugarcane bamboo hybridization is proving of undoubted scientific interest and its economic possibilities are being exploited by further hybridization in various directions. Two of the hybrids—with undoubted bamboo characters—are receiving special attention. One of these, which is a good mother parent, was crossed with Co. 356 (a sugarcane *sorghum* hybrid). Seed setting was good, and over 5,000 of these trigeneric hybrids are now in the field for full year studies. These hybrids have been crossed with the popular Coimbatore seedlings to improve quality and also back-crossed with the bamboo to further increase growth vigour.

Breeding technique.—A useful advance was made in the technique of bamboo hybridization by overcoming the initial difficulty of securing viable pollen for crossing. When a bamboo clump flowers individual bamboos are generally cut to the ground level and utilized as it generally dies out after flowering. The stumps left in the ground produce, under favourable conditions, a profusion of shoots most of which develop into inflorescence. Such stumps when carefully planted, even after transport over long distances, put forth inflorescences for fairly continuous periods, in some cases as long as three months. This has resulted in making available at the Station itself each morning fresh viable pollen in close proximity to the sugarcane mother parents. During previous years considerable time, energy and money had to be spent in exploring the neighbouring forests for flowering bamboos and arranging for the transport of pollen to the Experiment Station in viable condition, often over long distances.

The study of the bamboo flower has shown that the largest number of healthy pollen grains is from the first flush, and that in the third or last flush the pollen is practically infertile. This explains the erratic results with bamboo pollination obtained in previous years.

Types obtained.—The mature bamboo is both straight and erect, and certain of the F_2 plants show this character an asset of some importance in cultivation. The progeny also includes a fair number of heavy stoolers, perhaps from a combination of the under-ground branching of the bamboo with the close tillering of the sugarcane. Certain of these hybrids showed satisfactory juice qualities. Fourteen of these recorded in January over 16 per cent sucrose in juice and one over 19 per cent against the 16 per cent of the standards. The juices were particularly darkcoloured when unripe.

(2) INTERSPECIFIC AND INTER-VARIETAL HYBRIDS

It is hard to say whether an all-round ideal cane could ever be bred, but the country has already, both in its plantations and testing stations, quite a series of new canes both as general purpose canes and for special conditions and tracts. The canes in the plantations and cultivators' fields are already of such a high standard as compared to the ones grown before, that there has been an appreciable lowering in the cost of raw material—a very important condition for stabilising the industry against competition.

With the growth of the industry, it is becoming increasingly important to have in cultivation a cane which is "SAFE", in the sense that it would not only be resistant to pests and diseases, but also give satisfactory yields, through good and bad years. The performance of Co. 285 in the Punjab is a case in point. It is now sometime since Co. 285 was put out into the districts. It commands quite a large area in parts of the Punjab for its being a "SAFE" cane. Others like Co. 312 may give higher yields and better juices, but when pests or diseases take hold of the crop the advantage of the "SAFE" cane like Co. 285 becomes obvious.

The inter-varietal and inter-specific crosses made during the year were such as are likely to yield "SAFE" canes. The standard of selection is now high for all classes of canes, *viz.*, 'early', 'late' and 'general purpose' canes.

(3) FODDER CANES

Further progress has been recorded in the breeding of canes for possible use as fodder. One of the seedlings resulting from the cross *S. officinarum* *Sorghum halepense* was twice back-crossed with *Sorghum halepense*. The population includes plants which are both vigorous and soft-leaved. These are being planted for trial under the various conditions at the Station.

III. GENETICS OF SUGARCANE*

The cyto-genetical investigations conducted during the year have shown that the complex nature of inheritance in sugarcane is the direct result of

*The work described in this section is financed by the Imperial Council of Agricultural Research, and was in charge of Dr. E. K. Janaki Ammal,

their chromosome constitution. The chromosome number and their behaviour were studied in some of the more important Co. canes and they revealed them to be "triploids" and aneuploid progenies of "triploid. The chromosome behaviour of the cross *S. spontaneum** *S. barberi* approximates closely to that of an auto-triploid, and that of *S. officinarum* × *S. spontaneum* to that of an allo-triploid with auto-synesis.

Other interesting findings during the year are as below :—

(1) Sterility in Co. canes was found to be due to irregularities in chromosome behaviour rather than genic. In all cases pollen sterility is found to be more easily influenced by environment than ovule sterility.

(2) The inter-relationship of *Sorghum* and *Saccharum* has been brought closer by the discovery of certain species of para *Sorghum* in which the basic numbers vary from 5 to 7.

(3) Chromosome numbers of 76 clones of *S. spontaneum* collected from various parts of India were studied together with the range of their distribution. In all cases plants with fewer chromosome numbers were found to flower earlier.

IV. OTHER INVESTIGATIONS

Nitrogen contents of canes.—Work on the nitrogen contents of different sugarcane was started to investigate the suggested inverse relationship between nitrogen contents and "potential yielding capacity." Over 20 Coimbatore seedlings and other canes, whose performances are known, are under study from this view point.

Back crosses.—Certain rather interesting results have been obtained from back-crossing the hybrids with one of the parents. It has been found that when sugarcane is repeatedly thus back-crossed both with *Sorghum halepense* and *Sorghum durra* Stapf, the resultant hybrids display increasing resemblance to the *Sorghum* parent with added doses of *Sorghum* blood.

V. SUGARCANE BREEDING (MAINLY TROPICAL TYPES)*

1. HYBRIDIZATION

The breeding of the tropical types has now reached a stage when, after a study of a large number of crosses, definite combinations have been arrived at for evolving the desired type of canes. Over 100 crosses have been studied during the last half a dozen years and the study has brought out the fact that certain crosses can always be repeated on a large scale with advantage.

To assess the value of a cross a standard is now being used. No cross is considered satisfactory unless it conforms to this standard. The standard includes the following averages :—(a) 5 to 5.5 as the average for the number of tillers per seedling, (b) 10 to 12 lb. as the average weight per clump and (c) 15 per cent as the average for brix. Taking this standard, the crosses Co. 419 × Co. 413, Co. 419 × 247 B, P. O. J. 2878 × Co. 290, Co. 421 × Co. 419, Co. 421 × Co. 413, Co. 441 × 244, P. O. J. 2727 × Co. 281, P. O. J. 2725 × Co. 243, Vellai × Co. 243 and Co. 331 × Co. 360 have been found to be satisfactory.

Carried out by Mr. N. L. Dutt, Second Cane-Breeding Officer.

Co. 400 and P. O. J. 2725 when used as female parents give seedlings with thickish stalks, while Co. 419 and P. O. J. 2878 as pistillate parents yield seedlings with medium to thickish stalks. As regards brix, P. O. J. 2725 has been found to be the most useful female parent. P. O. J. 2878, Co. 421 and Co. 419 come next in order. The average brix from the seedlings of P. O. J. 2725 was 17.88 and 16.84 for P. O. J. 2878 seedlings, while Co. 421 and Co. 419 seedlings gave 15.96 and 16.59 brix respectively. Seedlings with good habit are obtained when P. O. J. 2727, Co. 285 and Co. 331 are used as parents, while bad habit results from Co. 244, Co. 408 and Co. 440.

2. SEEDLING AND TEST PLOTS

Co. 419 and Co. 421 again proved their utility as female parents, as the largest number of seedling selections during the year were from them. A feature of selection work during the year was the large number of early ripening seedlings that were selected for the test plot. Out of these about half a dozen appear to be promising and one or two are really very good as compared with the standards.

All the test Plots were kept carefully under observation and from the final plot three seedlings were raised to the status of Co. canes and distributed to the provinces for trial. These are Co. 457, Co. 458 and Co. 459, and their parentages are given elsewhere in this report.

3. FLORAL CHARACTERISTICS

Flower opening and anther dehiscence as also measurements of arrows were recorded in eighteen more varieties. The mode of emergence of the arrow, size of spikelets and the nature of the IV glume were also studied. Regarding the opening of the sessile and pedicelled spikelets, the former were noticed to open first in by far the largest majority of Co. canes. Only in three cases, viz. Co. 221, Co. 424 and Co. 525, the pedicelled spikelets were noticed mostly to open first. The rudimentary third styles was noticed in a number of varieties and in three cases, viz., Vellai, Co. 508 and *S. robustum* three fully developed styles with stigmatic branches were noticed.

4. PHOTO-PERIODISM

The photo-periodism experiments have given definite indications as to the stage at which extra illumination should be given so as to delay the time of flowering. When the extra illumination was given to one month, two months, and three months old plants it did not cause any appreciable delay in flowering. When extra illumination was given, however, to four and five months old plants, the flowering was noticed to have been delayed by eleven days in the variety Co. 285. The total extra illumination given was 250 hours with four 60 watt bulbs.

5. STOMATA

Observations were made on the nature, number and arrangement of stomata in certain sugarcane varieties. In P. O. J. 2725 and Co. 421 the stomata are bigger in size than those in Poovan and Vellai. The ratio of the stomata on the lower surface to those on the upper surface is of the order of 2.08 : 1 and 2.15 : 1 in Poovan and Vellai, respectively, as against 1.29 : 1 in Co. 421 and 1.98 : 1 in P. O. J. 2725.

6. VIABILITY OF SEEDS

Seeds of a few varieties were stored for two years over CaCl_2 and in an atmosphere of CO_2 . The seeds of Co. 419 and Co. 421 gave better germinations than Striped Mauritius, P. O. J. 2725 and P. O. J. 2878.

VI. SUGARCANE SUBSTATION, KARNAL*

Over 5,000 hybrid seedlings with Co. 421 as mother and Cos. 312, 313 and 393 as fathers were received from Coimbatore and grown for a full test. The cross Co. 421 $\times$ Co. 312 was found to be the most satisfactory regarding vigour of growth. Co. 421 $\times$ Co. 313 was comparatively richer but not sufficiently vigorous in growth, while Co. 421 $\times$ Co. 393 was good in habit but poor in growth. The studies during the year have brought out the merits of two Karnal selections, and both were raised to the status of Co. K. canes, viz., Co. K. 25 and Co. K. 26, and were distributed for trial to the sugarcane testing stations in the United Provinces and the Punjab.

VII. DISTRIBUTIONS

(1) AS SEEDS

Seeds of Co. 421 $\times$ Co. 331 were sent to the Economic Botanist, Shahjahanpur. A few seeds of two *Spontaneums* and two Noble canes were sent to Prof. B. N. Singh of the Benares Hindu University at his request. Seeds of *Erianthus* were sent to Dr. N. L. Bor, Forest Botanist, Dehra Dun. Seeds of Co. 419 $\times$ Co. 331 were despatched to the Director of Plant Breeding, Sydney, Australia.

2. AS SEEDLINGS

Over 5,000 seedlings of the crosses Co. 421 $\times$ Co. 312 Co. 421 $\times$ Co. 313 and Co. 421 $\times$ Co. 393 were despatched to the Substation at Karnal.

3. AS CANES

Nearly 200 individual packets representing about 50 varieties—mostly Coimbatore canes—were sent to about 30 places in India and three packets to Russia, four to Egypt and six to Natal (South Africa).

VIII. PERFORMANCE OF COIMBATORE CANES

1. IN INDIA

Co. 396 has shown some promise as an early cane and Co. 421 as a late cane in the experiment stations in the Punjab. At Shahjahanpur in the United Provinces Co. 421 has again established its superiority over Co. 312 in the medium and late varietal trials. Co. 356—a sugarcane $\times$ *sorghum* hybrid—has shown promise as a medium early variety in Bihar. Co. 381 is promising as an early and Co. 421 as a late cane in Bengal. Co. 432 has been tried as a salt-resistant variety at the Gosaba Farm (Bengal), and its *gur* has been found to be less salty in taste than that of Co. 213. Co. 419 and Co. 421 are promising

*This Substation at Karnal is financed by the Imperial Council of Agricultural Research.

both as plant and ratoon canes at Jorhat (Assam). For the tropical areas like the Madras and Bombay Presidencies Co. 419 has given very encouraging results.

2. FOREIGN COUNTRIES

Co. 281 and Co. 290 continue to be popular in certain foreign lands. Co. 432 has given the heaviest yield in the yield-trials in Portuguese East Africa. It has remained free of disease but shows rather low sucrose. Coimbatore canes have now taken a definite place in the standard varietal trials of most subtropical regions outside India.

IX. PARENTAGE OF COIMBATORE SEEDLINGS

Co. 457	.	.	.	.	.	.	.	P. O. J. 2725 × Co. 285.
Co. 458	.	.	.	.	.	.	.	Maur. 55 × Co. 285.
Co. 459	.	.	.	.	.	.	.	Co. 440 × S. W. 111.
Co. 546	.	.	.	.	.	.	.	} Co. 349 × Co. 331.
Co. 547	.	.	.	.	.	.	.	
Co. 548	.	.	.	.	.	.	.	Co. 421 × Co. 508.
Co. 549	.	.	.	.	.	.	.	(P. O. J. 2725 × <i>Sorghum durra</i> Stapf) × Co. 331.

X. PROGRAMME OF WORK

The breeding will be continued with the object of effecting further improvements with special emphasis on the breeding of 'early' and 'late' canes. Further attempts will be made to fully exploit the possibilities of trigeneric hybridizations, viz., sugarcane, *sorghum* and bamboo.

Studies will be continued on (1) factors affecting seed germination, (2) effect of photoperiodism on cane flowering and (3) causes of sterility in the sugarcane.

Cyto-genetic studies will be continued on the various species of *Saccharum* and its many hybrids to elucidate the genetic behaviour of *Saccharum*. The study of the cytology of the more popular Co. canes will also be continued.

REPORT OF THE IMPERIAL AGRICULTURAL CHEMIST

(B. VISWA NATH)

I. INTRODUCTION

The activities of the Section of Soil Science and Agricultural Chemistry during the year consisted of (1) post-graduate instruction in soils and agricultural chemistry, (2) research and investigation on problems connected with soils and crop growth, (3) the investigation of the scientific and economic questions involved in the utilisation of agricultural produce and in the disposal of the waste products of agriculture, and (4) analytical and advisory work for the other Sections of the Institute.

In addition to reporting on the work done during the year, a brief review is presented on the modern trend of thought and research on plant nutrition and contribution to that development by workers of the Section.

II. RESEARCH AND INVESTIGATIONS

1. SOILS

The work on soils during the year was in accordance with the programme laid down and was confined chiefly to the preparation of a soil map of India and to the comparative studies on virgin or uncultivated Indian soils.

Soil map of India.—As was stated in the previous year, the preparation of maps exhibiting important soil characteristics, has had to wait the completion of the projected soil studies. A map based on agricultural and colour nomenclature which has been in use in India for a long time both by the scientific and practical agriculturist, has been completed and was ready for forwarding for check by workers in the respective areas. This preliminary map classifies the soils of India into eight main prevalent categories—(1) alluvial, (2) coarse alluvial, (3) red soils lying on metamorphic rocks, (4) laterite soils, (5) black soils, (6) deep black soils, (7) light soils on trap rock, (8) deep black alluvial soils. The alluvial soils of extra-peninsular India are further divided into Indus alluvial, Gangetic alluvial and Brahmaputra alluvial soils. Another map based on climatic differences was also prepared but was still under check with reference to single value climatic factors and the normal geographical distribution of the major crop zones. A third map was prepared by plotting the relative nitrifying efficiencies of the surface soils. This shows a clearly demarcated central belt running north-east to south-west across the country at the boundary which divides peninsular and extra-peninsular India. The interpretation of this feature must await the completion of the larger programme of soil investigations in progress.

Soil studies.—These studies are a continuation of those of the previous year designed to obtain comparative data on the development and behaviour of soils under different geological and climatic influences that obtain in different parts of the country. The object is to classify obtain information on the future trends of soil processes and form a guide in the formulation of suitable and more efficient cultural and fertiliser practices. As a first step in these studies the analysis of soil profiles of uncultivated or virgin soils was commenced last year. The analyses were directed to ascertain the composition—both

mineralogical and chemical—of the clays which are the final products of rock weathering and the most reactive part of the soil. Although, the mineralogical composition deduced from the chemical analysis of clay may not indicate the mineralogical origin with respect to the parent rock, as the clays are mostly the result of secondary reactions in the processes of weathering, the analysis can give an intelligible picture of the trend of decomposition under varied climatic and regional environments and in relation to soil characteristics. The data on the analyses of all the profile samples of uncultivated soils are not ready but they are enough for a provisional consideration.

The soils of India offer a distinct contrast to those of many other countries in that they are very old, fully mature and do not show in many cases the pedogenic processes and the close relationship between the soil and its rocky substratum. The weathered materials in most cases have been transported to great distances by various agencies. The great majority of soils are of ancient alluvial origin and the so-called Indo-Gangetic alluvium comprises almost the entire portion of extra-peninsular India occupying the greater portion of Sind, Northern Rajputana, the Punjab, the United Provinces, Bihar, Bengal and Assam. This area may again be divided into three main divisions, the Indus alluvium, the Gangetic alluvium and the Brahmaputra alluvium. These can again be divided into sub-mountain and plains regions. These alluvia were originally derived from the rocks of the Himalayan range of mountains.

The peninsular India represents the ancient table land, a large area of which is covered by the ancient and the earliest formed gneisses and schists. The series of rocks known as Dharwar series are considered the upper and younger members of the archaen rocks. On the weathered and denuded edges of the Dharwar rocks and associated with gneissic rocks, a series of thick sedimentary formations of varying thickness are found. The thick ones are called the Cuddapah formations and the thin ones the Karnool formations. Similar formations lying on folded Dharwar rocks occur in the Vindhyan system of rocks of the Aravalli hills. A colossal volcanic eruption sometime after the Vindhyan epoch, brought the Deccan trap rock into being.

The examination of the soils derived from these varied geological forms of rocks has shown that although the nature and composition of the soils reflect to some extent the composition of the original rocks from which they are derived, the main trend of weathering and its final result are influenced to a considerable extent by the climatic complex, particularly by the amount and the seasonal distribution of rainfall. In India the unique monsoonic division of the year into dry and wet periods and the high temperatures that prevail, considerably influence the character and the sub-aerial denudation of the surface of the country. Compared to the soils of the temperate zones, the aerial and soil temperatures in India are higher by as much as 10 to 20 degrees Centigrade or more and, therefore, all chemical reactions involved in the soil and plant processes proceed many times more intensively. The high temperatures and humidity function so intensively that chemical decomposition follows almost at the heels of rock disintegration and is the more conspicuous feature of the soil processes in the plains. The result is that irrespective of the nature of the original rocks from which the soils are derived the forward reactions of normal weathering and the secondary reactions resulting

from the shifting equilibrium on the basis of solubility and interactions have tended towards the direction dictated by the climatic complex of the locality.

Therefore, it would appear that a system of grouping or classification based on climate as the predominant function assumes a particular significance in connection with the practical aspects of soil utilisation and land development. In assessing the relationship between soil and its climatic complex (temperature, precipitation and evaporation) neither the rain factor proposed by Lang nor Meyer's N—S quotient which is obtained by dividing the value for precipitation by the value for saturation deficit is entirely satisfactory. An additional factor, the degree of wetness, is being investigated. Meanwhile a division has been made into four broad divisions beginning with arid in the west and passing eastward through semi-arid and humid into per-humid zones.

The soils of the arid zone are characterised by high base saturation, and both calcium and sodium are in excess over magnesium and potassium. About 80 per cent of the silica is in the soluble form. The soils are of a light pink colour due probably to their being residues of syenitic rocks and by interaction with colloidal silicic acid which is not removed owing to scanty rainfall a thin coating of iron oxide is formed on the silica particles. The silica-sesquioxide ratio of 2.91 and Kaolinisation are indications of maturity.

The soils under semi-arid and humid conditions are developed from almost all types of rock systems and are either brown, black or red. It would appear from the analytical data that the soils are not always residues which have survived weathering but in many cases are adsorption complexes of iron oxides and silicic acid. Those derived from lime stones are richer in lime content but more alkaline, as for example the soil from Surat developed from *Nummulites* and that of Tabiji which is derived from igneous lime stones. These soils developed under semi-arid and humid conditions contain proportionately greater amounts of silicic acid, consequent on the removal of the bases of the alkali and alkaline earth metals. Base saturation of the silica is lower than in the case of arid soils.

Soils developed under per-humid conditions show distinctly the effects of leaching action.

The average values for the molecular composition worked from the data so far available and the sesquioxide ratios of clays from soils differentiated on the basis N—S quotient work out as given below.

Type	Combined SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Combined SiO ₂	Combined SiO ₂	Combined SiO ₂
								R ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃
Arid . . .	0.595	0.056	0.208	0.056	0.069	0.043	0.051	2.26	10.59	2.88
Semi-Arid . .	0.688	0.066	0.216	0.037	0.059	0.026	0.059	2.38	10.73	3.08
Humid . . .	0.664	0.079	0.243	0.024	0.036	0.020	0.027	2.09	8.59	2.78
Per-Humid . .	0.601	0.062	0.246	0.010	0.028	0.023	0.030	1.99	9.96	2.52

During development, these soils acquire colours depending on the prevailing local conditions of climate and source of origin. Agronomically black and red soils are distinguished and are invested with specific agricultural qualities. The black soils which are different from peaty and other forest soils rich in organic matter and from the black soils of swamps, are highly siliceous and the clays contain high amounts of alkalies and alkaline earth bases. A variety

of rock systems under semi-arid and semi-humid conditions give rise to these soils. The high silica alumina ratio (3·39) shows that they are highly Kaolinitic and have adsorbed alkalis to a great extent. The red soils, which are also derived from the same rocks as black soils, have clays with low lime content. The molecular composition of the clay fractions from soils as also the total iron content of whole soils on the basis of colour classification can be seen in the statements below.

Average molecular composition and ratios of clay from soils classified on the basis of colour

Soil Colour	Com- bined SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Com- bined SiO ₂	Com- bined SiO ₂	Com- bined SiO ₂	Com- bined SiO ₂
								R ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃	Bases.
Black .	0·752	0·069	0·225	0·035	0·066	0·017	0·035	2·59	11·31	3·39	1·69
Brown .	0·650	0·068	0·239	0·023	0·026	0·023	0·035	2·15	9·83	2·78	1·62
Red .	0·579	0·073	0·256	0·008	0·020	0·016	0·018	1·66	8·38	2·09	1·42
Pink .	0·615	0·060	0·211	0·051	0·062	0·040	0·065	2·28	10·44	2·93	1·27

Total iron content of soils

	Maximum per cent	Minimum per cent	Mean	Number of samples
Indo-Gangetic alluvium	7·60	2·30	4·8	12
Brown alluvium—South India	17·30	4·84	8·8	6
Black soils	11·50	4·34	7·1	18
Red soils	7·10	3·50	5·5	7
Laterite (so called)	48·71	6·12	19·2	8
Red soils of hills	11·91	9·08	10·1	6

The differentiation of soil profiles into horizons and layers depends on the processes mainly connected with the movements of water in the soil.

The analyses of the aqueous extracts of the soils have given useful indications regarding anions and cations which play an important role in the soil solution. Striking differences, which may allow characterisation into types, have been noticed. On the basis of the concentration of water-soluble salts and their depth distribution in the profile, five main groups may be formed. (1) Profiles in which the concentration of soluble salts is the highest at the surface and lowest at the bottom (*i.e.*, 5 feet to which the profiles have been taken), (2) profiles in which the highest salt concentration is at the surface and the lowest somewhere in the middle of the profile, (3) profiles in which the highest salt concentration occurs somewhere in the middle while the lowest concentration is either at the surface or at the bottom, (4) profiles in which salt concentration is maximum at the bottom and lowest either at the surface or somewhere in the middle, and (5) profiles with concentration more or less uniform throughout and the total quantities of them are very low. This division may be found ultimately to be too fine and may need revision when the full data become available.

In the profiles of the first group sodium and chlorine predominate, while in the second the sulphate radicle is either very low or absent. The third

group is characterised by the predominance of either calcium or sodium and sulphate or chloride. The fourth group is characterised by very high salt concentration, while the fifth contains very low amount of salts.

Further data on the base exchange capacity of the profiles fall in a line with those obtained during the previous year and generally support the observations then made. The profiles of the uncultivated soils in places of low and medium rainfall do not show much variation in the depth distribution of the exchangeable bases. In the arid and semi-arid regions calcium constitutes 70 to 80 per cent of the total exchangeable bases, while magnesium, potassium and sodium together vary between 5 and 15 per cent. In humid and perhumid regions the exchangeable calcium is lower at the surface than in the deeper layers.

The total exchangeable capacities of the surface soils considered in terms of climatic classification and colour classification, are given below in milli-equivalents per 100 grams. of soil.

Arid	.	.	.	.	.	.	.	.	10.5
Semi-arid	.	.	.	.	.	.	.	.	30.0
Humid	.	.	.	.	.	.	.	.	31.3
Per-humid	.	.	.	.	.	.	.	.	13.7
Black soils	.	.	.	.	.	.	.	.	52.8
Brown soils	.	.	.	.	.	.	.	.	23.3
Red soils	.	.	.	.	.	.	.	.	13.5
Pinkish soils (largely of the Indo-Gangetic alluvia)	.	.	.	.	.	.	.	.	8.0

When, however, the values are calculated to exchange capacity in milli-equivalents per 100 gm. of clay, on the assumption that the exchange capacity resides entirely in the clay fraction of the soil, these large differences vanish

Base Exchange capacity of 100 grms. clay in M. E.

Arid	.	.	.	.	.	.	.	.	64.3
Semi-arid	.	.	.	.	.	.	.	.	72.8
Humid	.	.	.	.	.	.	.	.	74.3
Per-humid	.	.	.	.	.	.	.	.	84.3
Black soils	.	.	.	.	.	.	.	.	84.3
Brown soils	.	.	.	.	.	.	.	.	105.2
Red soils	.	.	.	.	.	.	.	.	58.2
Pinkish soils of the Indo-Gangetic alluvia	.	.	.	.	.	.	.	.	62.4

Usually 0.5 to 1.0 milli-equivalent is accepted as the range for the base-exchange capacity of mineral colloids, and the results are within these limits in all the types of soils examined. But the results obtained so far do not indicate that base-exchange capacity is positively correlated with the clay content. The black soils contain the largest amount of clay, but the latter do not appear to possess the highest efficiency in base-exchange capacity. This is presumably due to the secondary reactions under the influence of climatic factors.

What has been said just now will be evident from the figures of analyses of clays for their alkaline and alkaline earth metals.

Clay analyses—per cent on dry basis

Annual rainfall inches	8.5	23.2	49.3	60.0	102.6
M. M.	216.0	590.0	1,251.0	1,525.0	2,605.0
Temp. degrees Centigrade	25.1	25.3	26.3	26.3	25.0
CaO.	3.06	2.31	1.20	1.37	0.48
MgO.	2.21	2.76	1.21	0.96	1.30
K ₂ O.	3.56	2.63	1.99	2.10	2.00
Na ₂ O.	4.07	3.40	1.37	1.80	1.71
Per cent total water soluble salts on whole soil	0.139	0.080	0.039	0.064	0.053

If the values for the various constituents are plotted against the ratio of rainfall to temperature, the evidence of secondary reactions is seen more clearly. The adsorption of Na₂O, K₂O and CaO has taken place under a low rainfall of 8.5 inches per annum, and owing to the chemical stability of the clay complex and moisture deficiency, magnesium silicates have been left comparatively unacted upon. Under 50 to 60 inches of rainfall, aided by the high prevailing temperature, conditions would be favourable for dissociation and the formation of hydrogen clay which reacting with the soluble electrolytes present in the system forms adsorption systems. The upward movement of the electrolytes will be quite pronounced due to the prevailing high temperature. Under conditions of greater precipitation following intense heat and drying all the cations except MgO move out, the CaO moving the most quickly and easily. This is followed by the entry of magnesium in the clay complex not only in the adsorbed state but also into the lattice structure.

The data so far available on the carbon and nitrogen contents of the profiles show that the ratio of carbon to nitrogen in the surface soils varies from 5.1 to 23.6, though in several cases it is round about 10. The wide ratios are noticeable more particularly in a belt the soils of which exhibit weak nitrifying power as judged by comparative nitrification studies in the laboratory. The ratios do not show any striking feature in the various depths in the profile. Considering the carbon-nitrogen ratios in respect to soil and climate, it would be expected in the light of observations by others that the nitrogen content of the soil would be a function of the mean annual temperature and humidity and would decrease exponentially with increasing temperature. Such a relationship has been extended to organic carbon also. When, however, the available data for surface soils are plotted on the map at the places from which the soils were collected they appear to fall into three distinct regions. Those with ratios between 12 to 20 fall in one region, with ratios 10 to 12 fall in another region while those with values below ten form a separate region.

Soil types and methods of tillage or cultivation.—The chief objective of the soil studies is to assess the inherent and acquired soil characteristics in terms of efficiency in crop production. Inherent soil characteristics are those traceable directly to the parent material and to the influence of the climatic complex. These have been dealt with in the foregoing. Acquired characteristics are those physico-chemical, bio-geological and agrobiological manifestations resulting from such primary operations as (1) tillage leading to macro and micro structural alterations in the gross body or smaller aggregates of the soil and (2) irrigation leading to salinity and alkalinity accompanied by their consequential effects on the soil in relation to crop growth.

The available data on crop yields resulting from different kinds of tillage and cultivation experiments were collected and these were under examination with reference to varied soil characters under varied climates. The results from the several experimental stations have been classified as comparative data of crop yields obtained with the use of inversion and no inversion ploughs ; by deep and shallow ploughing ; frequency of deep ploughing ; seed bed preparation by ploughing and interculture versus no interculture.

The use of inversion ploughs did not, on the whole, result in increase in crop yield, although in the very early years, in some cases, when the land was relatively rich, inversion plough appeared to be slightly beneficial. Where the trials continued for long periods, there was clear tendency towards a decline in crop yields by the use of inversion ploughs. The results of intercultural experiments are of a varied nature and will have to be examined in relation to soil characteristics and climatic influences.

Nitrogen transformations in soils.—*Nitrification.*—Investigations on the effect of sunlight on nitrification were continued. In the previous reports it was stated that the results of experiments on the effect of sunlight on the nitrification of either ammonium sulphate or of solutions of sodium nitrite were of a negative character. Further experiments during the year showed that sunlight had a decided check on the process of nitrification, as the following typical results of several experiments show.

Milligrammes nitrate nitrogen per 100 gm soil.

	After one month at laboratory temperature 22°-24°C.	At the end of two months. First month at 22°-24°C. second month at 30° in the incubator.	At the end of three months. First month at 22°-24°C. and next two months at 30°C. in the incubator.
Exposed to sun for one hour daily . . .	10.8	12.0	19.2
Exposed to sun for two hours daily . . .	3.6	7.2	12.0
Exposed to sun for three hours daily . . .	2.4	7.2	12.0
Exposed to sun for four hours daily . . .	0.9	3.6	9.6
Exposed to sun for six hours daily . . .	1.2	3.6	9.6
Not exposed to sun. . .	2.4	13.2	19.2

Loss of elemental nitrogen from soils.—When all the different forms of nitrogen in the course of nitrification of ammonium sulphate in soil are totalled up, there has always been found a shortage to be accounted for *i.e.*, a difference between the total nitrogen in the soil *plus* the nitrogen added for nitrification, indicating a loss of nitrogen during the process. A series of experiments were set up to ascertain if the loss occurred from the soil as elemental nitrogen. Quantities of soils with and without ammonium sulphate were enclosed in a volume of oxygen-air mixture containing known volumes of nitrogen and

oxygen. The whole system was maintained gas proof throughout the experiment. At the end of six weeks, when a major part of the added nitrogen had nitrified in unenclosed controls, the complete volume of gas enclosed with the soils was removed by displacement with water and the nitrogen gas in the mixture was estimated. This showed an excess of nitrogen representing a loss of 7.7 per cent of the combined nitrogen added to the soil. These are the results of experiments conducted in the laboratory. Under field conditions and in sunlight the losses would necessarily be much higher. In another series of experiments, nitrogen losses amounting up to forty per cent of added ammonium sulphate have been observed on the field scale.

The energetics of carbon and nitrogen fixation in natural systems.—Mr. B. Rama Moorty continued his study on the energetics and the physico-chemical mechanism of carbon and nitrogen cycles in nature and has obtained results which show that carbon and nitrogen fixations in nature are partly the results of energy transfers in oxidation and reduction reactions and are complementary and reciprocal. These studies are the outcome of the enquiry into the significance of loss of nitrogen following the process of nitrification on the one hand and the fixation of nitrogen on the other, when nitrogenous substances are added to the soil. It has been shown from spectroscopic investigations by others that the vibrational and translational energy of colliding molecules is in equilibrium distribution with the chemical energy as it is being produced and that the energy is transferred to the colliding molecule. It has been further shown that the oxidation of phosphorous is propagated by energy chains and that by collision with other molecules the chains are broken. There is, however, no information on what happens to the energy. This energy must affect the vibrational and translational energy of the de-activating molecule and so the de-activating molecule must itself have been activated depending on the sufficiency or otherwise of the quantum of energy available. If this assumption is correct the slow atmospheric oxidation of phosphorous should result in the production of some compounds of nitrogen. On this assumption Mr. Rama Moorty has shown experimentally that slow atmospheric oxidations of phosphorous and of simple carbohydrates in an atmosphere free from combined nitrogen resulted in the production of nitrides of tin and magnesium, and of ammoniacal and nitrous compounds according to the nature of the experiment. The oxidation of sugar was carried out at the temperature of boiling water and so there could be no bacterial intervention. The experiment on the oxidation of phosphorous has the advantage that it leaves no manner of doubt that any fixed or combined nitrogen recovered at the receiving end of the reaction apparatus is the result of direct chemical combination and cannot be attributed to the activity of micro-organisms. Extending the concept of the transfer of chemical energy, it should be possible to effect carbon fixation as the result of oxidation of ammonia or nitrogen compounds. The validity of this assumption has been tested by experiments with pure substances and with soil. Studies are in progress to elucidate the mechanism of carbon nitrogen fixation in soils and other biological systems in the light of the observations made above.

2. Manures, Fertilisers and Plant Nutrition

In close association with soil studies, the study of crop nutrition was in progress. Considerable as has been our knowledge of the use of manures and fertilisers for food and commercial crops, there are still several problems of

plant nutrition on which precise information is required. The effect of soil conditions and of fertilisers on plant metabolism and on the quantity and quality of crops is one of fundamental importance. The quality problem, which is comparatively new and on which this Section has some pioneering work to its credit, has reached a stage at which a review of the progress will be helpful in securing a proper perspective of the subject in its scientific and practical aspects.

Soil conditions and manuring in relation to quantity and quality of crops.—

As the consequence of Leibig's mineral theory of plant nutrition enunciated a century ago, there has developed in recent years the agro-biological concept which seeks to interpret crop yields in terms of the major fertiliser constituents on the assumption that all plants respond in a similar manner to applications of fertilisers. The weakness of this concept lies in the fact that too much stress has been laid on the effect factors of fertiliser constituents jointly and severally and too little on the climatic, varietal and species differences in nutritional requirements of plants and too little is known of the fundamental aspects of plant nutrition and metabolism as a whole.

In 1926 and in subsequent years the writer of this report, as the result of his own investigations and those carried out in collaboration with Sir Robert McCarrison, had called attention to the following experimental findings.

1. The fundamental nutritional requirements of plants are similar to those of animals and human beings in that they require accessory food factors similar to vitamins, for proper development and reproduction.
2. Organic manures, exemplified by cattle manure, have as one of their functions the supply of these accessory food factors.
3. There exists a cycle or chain of the accessory or growth factors which has been defined as, soil—organic matter—microorganisms—plant—animal—microorganism *cum* organic matter—soil.
4. Soil conditions and the nature of manures or fertilisers available for the nutrition of the plant modify the composition and the *seed* and nutritive value of the produce.

These findings not only did not receive general acceptance but even roused opposition, due partly to our knowledge on the problem being incomplete and partly to the difficulties experienced in getting out of the narrow view points resulting from a too limited experience. In the few years that have elapsed sufficient data have been obtained in different parts of the world with the result that all the views expressed above have gradually come to be appreciated or recognised. In order to arrive at a clear understanding of the position and to make more definite manurial and fertiliser research programme and policy it is useful to briefly survey the more important recent developments pertaining to the subject and to examine their implications on the science and practice of crop growth.

Till the year 1840, it was believed that plants should be nourished by substances of an organic nature. Leibig's mineral theory of plant nutrition dismissed the old view, and simplified the problems of soil and plant nutrition. It was felt that if the constituent indicated as inadequate or deficient by a

chemical analysis of the soil be supplied to the soil in the form of inorganic salt all would go well. Bottomley (Proc. Roy. Soc. B. 88 : 237, 1914) and Mockeridge (Proc. Roy. Soc. B. 89 : 508, 1917) experimenting with aquatic plants and in water cultures stated for the first time that extracts of fermented manures gave certain growth promoting substances which they called "*auximones*" and which they considered essential to plants just like vitamins are to animals. This view was vigorously opposed and Mockeridge in a later communication (Ann. Bot. 38 : 723, 1924) abandoned her former views.

Viswa Nath and Suryanarayana (Jour. Madras Agric. Students' Union 14 : 19, 1926 ; Mem. Dep. Agr. Ind. Chem. Series 9 : 85, 1927) in association with McCarrison (Ind. Jour. Med. Res. 14 : 351, 1926) from the results of their independent and complementary studies with wheat and millets in soil cultures in pots and in the field demonstrated the existence of a cycle of growth factors in nature. They have shown that manurial and fertiliser applications are capable of reacting on plants not only by increasing yields but also by affecting the quality of the resulting seed in showing that seed raised on soils poor in organic matter and with artificial fertilisers gave an inferior crop than that raised with farm yard manure. Using the same grain as was used in the crop experiments, McCarrison observed that the nutritional value of the grain to rats varied in a similar manner and he attributed the nutritional difference to differences in the vitamin content of the grain. The observation that the same grain as had provided better nutritive value has also given better seedling suggested that grain raised with organic manure is richer in vitamins and in some constituent that stimulated plant growth and that the plant growth stimulant and the vitamin might be either the same or at least so interrelated that the so called stimulant enabled normal plant metabolism. Direct experiments carried out with produce obtained by manuring with brewery yeast in field plots in vegetation and animal nutrition tests and comparative experiments with farm yard manure extracts and yeast extracts provided evidence of the function of microorganisms in the process and of the existence of the chain or cycle of the so called accessory food factors of organic nature.

Although the foregoing results were confirmed by several workers, the existence and the necessity of accessory food factors for plant growth and development was debated and the superiority of organic manures and their extracts in plant nutrition was attributed by several workers either to the influence of iron or to trace elements. The Royal Society of London held a discussion at which the available data on the subject were considered in the summer of 1937 (Proc. Roy. Soc. B. 124 : 1, 1937). In this discussion the position was clarified and the existence of growth factors for the vegetable kingdom has been recognised. Nature (140 : 161, 1937) in reporting the substance of the discussion stated that the case established in the nutrition of animals is equally established in the nutrition of the most diverse varieties of cells ; namely, that all cells from the lowliest bacterium to the cells of the highest animals are enabled to carry out the series of reactions leading to the production of energy and growth by the help of other substances mostly of the nature of vitamins in animal nutrition.

The brilliant work of Kogl which led to the isolation of *auxins*—the substances concerned with the growth of plants—in a crystalline form from urine, malt, yeast, liquid manure and farm yard manure has been a big step in advance. Auxins or phytohormones have been shown to play a definite role

in many life processes of plants. Kogl (Chemistry and Industry 57 : 49, 1937) has recognised the existence of a cycle of growth factors in nature. The work of Thimman (Jour. Gen. Physiol. 18 : 23, 1934) and that of Link (Bot. Gaz. 98 : 816, 1937) indicates the role of micro organisms as contributing factors for the stimulation and regulation of plant processes. Link (Nature 140 : 507, 1937) and several other workers have brought forward evidence in support of the statement that the effects of green manuring, dung, urine, compost and humus soils may be due to the hetero-auxin or similar substances produced by fermentation.

Tallarico (Mem. Accad. Italia Biol 3 (1) : 5—325, 1932) carried out experiments which showed that natural manures showed specific effects not exerted by artificial fertilisers and generally that seeds from plants that are over nourished during the growth period have less vitality than seeds from a poorer soil. He has further observed that seeds grown under arid conditions have a greater germinating power and more vitality than seeds grown under humid conditions. Thompson (Proc. Amer. Soc. Horti. Sci. 34 : 599, 1937) has drawn attention to the influence of fertiliser treatment and time of ripening on the germination of lettuce seed. Beuchamp and Lazo (Int. Sug. J. 41 : 70, 1939) discussing the relation between vigour of seed and nutritive elements in sugarcane setts have stated that in the case of two months ratoon cane shoots, the vigour of the " seed " appeared to depend on reserve nutrients. Kruger (Landw. Jahrb 66 : 781, 1927; Bied. Zentra 57 : 156, 1928), Kottmeier (Kuhn. Arch. 15) found the quality of seed potatoes distinctly influenced by manuring. Calcium cyanamide and sodium nitrate gave poorer seed material compared to farm yard manure. Pfaff and Roth (Biochem. Z 297 : 137, 1938) reports that barley grains with a high nitrogen and vitamin B content have a higher rate of germination than those with a low content and that young plants grown from the former are superior in growth ability as well as in chlorophyll and vitamin content.

Viswa Nath (1927 loc. cit.) and McCarrison (1927 loc. cit.) showed that the nutritional value of grains and herbage depends on the environmental conditions such as soil, moisture and fertilisers. Tallarico in 1932 (loc. cit.) reported the results of experiments in which young turkeys fed on grains grown with stable manure came through the critical period of growth with fewer deaths and greater vitality than those fed on grains grown with chemical fertilisers. Rowland and Wilkinson (Bio.-Chem. J. 1933) record the results of tests in which seeds from a grass plot manured with cattle manure had a higher nutritive and curative value than those from a plot fertilised with artificial fertilisers.

Wachholder and Nehring (Bodenk. Pflanzenernhr, 9/10 : 708, 1938) have stated that in general the value for tubers manured with farm yard manure was greater and less affected by cooking than those for tubers grown with mineral fertilisers only.

Nalivkin (Abst. Chem. and Ind.) investigating the effect of fertilisers on crop yield and grain quality of certain wheats reported that the best results are obtained with farm manure.

The work of Thomas and Thompson of the King's College, Newcastle-on-Tyne (Jour. Soc. Chem. Ind. 57 : 210, 1938) on the composition of grass under manuring, has shown that protein digestibility varies with the nature of

manuring. With grass raised with dung alone, dung *plus* phosphate alone showed 64 to 69 per cent protein digestibility. In the case of grass raised with ammonium sulphate alone or without manure the protein digestibility was 58 per cent. These results lend strong support to those obtained by Viswa Nath (Ann. Rep. 1933-34 to 1937-38) with differently manured millets and wheat. According to him high nitrogenous manuring does not necessarily increase the protein content although the nitrogen content of the grain and herbage may be increased. This is further supported by the investigations of Smallfuss (Phytopath. Z. 5 : 207, 1937) who observed that high nitrogen content in plants resulting from excess of nitrogen supply is due to an increased proportion of soluble nitrogen rather than protein nitrogen. Likewise, Rudolph Berks (Bodenk. U. Pflanz. 12 : 129, 1939) from an examination of mature grains of wheat, barley and oats stated that nitrogen increased absolutely with its increased application to the soil but that the excess nitrogen accumulated as amides. In similar experiments with wheat, Walter Baumeister (Bodenk. U. Pflanz. 12 : 175, 1939) reported similar conclusions on the modification of the composition of wheat by fertiliser treatment.

Howard in the course of a lecture (Chemistry and Industry) stated that wheat straw from fields manured partly with organic matter has been found to last as thatch for ten years while straw from similar land manured with artificials lasts five years. This observation, according to Howard, has for its basis the careful records kept on Viscount Lymington's estates in Hampshire. Howard has further referred to the definite experience and views of merchants in Worcestershire and of a grower in Walton-on-Thames that the highest quality of crops are always produced with farmyard manure.

In regard to the effect of environment and treatment on commercial and medicinal crops Dafert has very recently (1938) reviewed the results of published and unpublished data in which the effect of inorganic and organic fertilisers on the formation of active plant constituents such as alkaloids, glucosides, and essential oils has been described.

It should, however, be noted that as would be expected, there are also results which show no influence of fertilisers either on the course of plant metabolism or in regard to the nature, composition, digestibility, nutritive value or other physiological activity of the plant products. The trend of recent research and thought, however, is the growing recognition that so far considerations of quantity in crop production dominated and that it is time that attention was paid to quality. In his presidential address to the Agricultural Section of the American Association for the Advancement of Science, Auchter (Science 89 : 421, 1939) has called attention to the inter-relationship in soil, plant, animal and human nutrition and stated that it would be no revolutionary step to think in terms of nutritional quality as well. Wrench (Brit. Med. J., February 11 : 1939, p. 276) in an article on soil and health stressed the importance of well nourished soil and plants to the health of animals and human beings. Pfaff and Pfuetzer (Angewandte Chemie 1937) in the course of a review of German experiments, state that manures and fertilisers not only tend to stimulate growth and increase crops, but also add to the vitamin content to the extent of one hundred per cent in some cases and that the result of the tests varied according to the soil and that plants grown in rich and fertile soil were superior as to the percentage of their vitamins.

The foregoing account has necessarily to be brief. Still, it provides support for Viswa Nath's observations made thirteen years ago and which are important from the philosophical and practical stand points. From the philosophical point of view, the evidence reveals continuity in the apparently discontinuous and diverse manifestations seen in the system soil—plant—animal and in establishing the great generalisation of the universal nature of the fundamental principles of nutrition and of the similarity in the basic mechanism of life. From the practical point of view, it is seen that the largest crop is not necessarily the best and that it may be lacking in the qualities essential for nutrition, medicine, commerce or industry.

There is little doubt that a new and important and vast field of research in soil nutrition and plant nutrition is opened up and much work has to be done before we reach the stage of discovering the measures by which the metabolism of the plant can be controlled to ensure the greatest possible quantity and quality.

In the course of the examination of the experimental files in the Chemical section of the Institute, the following unpublished results of the late Dr. J. W. Leather are of interest in showing how soils and fertilisers influence the starch and protein contents of grain. These results must have been obtained by Dr. Leather before he left India in 1917. The experiments were carried out at Pusa in pot cultures.

Change in the nitrogen and starch contents of grain by manuring.—
Manures :

N at 50 mgm. per kilo as $\text{Ca}(\text{NO}_3)_2$	} In jars of 15 kilo capacity.
P at 100 mgm. per kilo as super	
K at 50 mgm. per kilo as K_2SO_4	

N was determined by Kjeldahl method; starch by Sullivan's method using malt diastase.

Soil	Crop	Treatment	N Percentage on dry substance	Percentage of Starch
Shillong	Maize	Nil	1.98	58.1
"	"	N	2.52	54.7
"	"	N+P	1.73	61.6
"	"	N+P (duplicate pot)	1.83	61.4
"	"	N+P+K	1.94	60.2
"	"	N+P+K (duplicate)	1.97	59.1
Akola	"	N	2.32	55.8
"	"	N+P	1.96	58.2
"	"	N+P+K	1.57	60.7
Palur	"	Nil	2.05	56.0
"	"	N	1.75	58.5
"	"	N+P	1.96	57.5
"	"	N+P+K	2.06	57.2

Soil	Crop	Treatment	N Percentage on dry substance	Percentage of Starch.
Pusa	Kado	Nil	0.87	51.4
"	"	N	1.05	50.1
"	"	N+P	0.92	50.9
Pusa	Marva	Nil	1.32	59.3
"	"	N	1.96	56.3
"	"	N+P	1.23	62.3
"	"	N+P	1.31	58.8
Pusa	Rice	Nil	1.22	56.4
"	"	N	1.63	54.9
"	"	N+P	1.17	57.5

Leather followed up these experiments by another set of interesting experiments with hard grey *gangajali* wheat, which was sown in jars of Pusa soil, some which were unmanured whilst to others fertilisers were added. The produce analysed as follows:—

	Weight of 100 gm. seeds	N %	Starch %
A. Original seed	3.5	2.57	50.90
B. Grown in pots (no manure)	2.5	2.85	49.55
C. Grown in pots with N	2.1	4.44	40.59
D. Grown in pots with N+P	4.1	1.60	57.50
E. Grown in pots with N+P+K	3.9	1.76	55.50

In the next season seed from B (no manure) was grown with oilcake and superphosphate and seed from D (calcium cyanamide and super) was grown without manure and with oilcake and superphosphate.

Seed from B.	Grown again without manure	2.6	3.19	..
	With oilcake and super	3.6	1.55	58.37
Seed from D.	Without manure	2.3	3.26	..
	With oilcake and super	3.3	1.85	57.10

During the year under report an investigation was commenced to study the variation in the composition due to soil conditions. By the courtesy of the Imperial Economic Botanist, who very kindly supplied samples of strains of his well known wheats, a study of variation in the content of nitrogen with respect to variety and environment was in progress. The wheats from 1938 harvest of crops grown at Delhi, Karnal and Pusa were under examination.

Variety	Grown at		
	Delhi	Karnal	Pusa
P. 114	12.53±0.000	11.98±0.005	12.75±0.005
P. 4	11.48±0.008	9.92±0.006	12.52±0.007
P. 165	9.49±0.024	10.28±0.037	12.52±0.004
P. 120	11.15±0.006	11.53±0.002	11.43±0.026
P. 111	10.00±0.05	9.52±0.007	12.77±0.004
P. 112	10.80±0.08	9.35±0.005	12.59±0.002
P. 80.5	9.60±0.03	12.62±0.005	12.17±0.002
P. 125	9.18±0.004	..	10.96±0.004

Fixation of nitrogen by the maize plant.—Further experiments were carried out, to ascertain if the maize plant could fix elemental atmospheric nitrogen. Repeat experiments on the lines mentioned in the previous report, gave again results showing the power of the maize plant to fix atmospheric nitrogen. Inoculation with maize root organisms did not make much difference in the fixation of nitrogen. Careful gasometric experiments in which the seed was germinated and grown in a known volume of air devoid of all combined nitrogen, gave results showing that the maize plant absorbed nitrogen during germination and growth.

Varietal differences in plant nutrition.—Differential response of varieties is in part due to the differences in soil types, the availability of moisture in them and the prevailing temperature conditions. The capacity for absorption of moisture and the rate of germination are to a great extent dependant on the ease with which each soil can deliver moisture to the seed. The tissue moistness of the seed of the three varieties appear to have, if any, very little influence on the differential behaviour but the bound water exercises an influence. This is noticed in the hybrid P 165 and Parent P₄ but in P₁₂ these differences at lower temperature (10°C) are clearer than at 31°C.

Bacterial cyclostage associated with sugarcane mosaic.—In the report for 1937-38, a detailed review was given on the progress of the work on the bacterial cyclostage associated with sugarcane mosaic. The work was continued during the year under report. In the filtrates of the juices of leaves of mosaic affected sugarcane, made in April, May and up to June 15th, 1938, the usual bacterial growths occurred in the months of June, July and August 1938, respectively. The bacterial growths were found to be similar to those observed previously and the tests confirmed the previous findings. As would be expected in the light of previous observations, no growths appeared in the filtrates of mosaic affected sugarcane leaf made after the break of monsoon in June 1938. No growth appeared by the end of June in the filtrates made in April, May and June of this year. Experiments were under way to see if the organisms could be isolated from healthy cane infected with mosaic. Plants were grown in pots and inoculations were made. One set of mosaic and healthy leaves were sampled and their juices were submitted to the usual technique. No growths have appeared yet.

III. INVESTIGATIONS ON AGRICULTURAL PRODUCE AND INDUSTRIES

1. SUGARCANE AND GUR STUDIES

Two lines of work have been in progress. One is the practical aspect by which tests are carried out on the scale and under the conditions that obtain with the cultivator. The other is the study of the chemical aspects of sugarcane with special reference to the constituents responsible for colour, structure and keeping quality of gur and to devise more efficient but equally simple methods of handling juice in the open pan boiling process for the production of gur and where sugar is made for the recovery of more and better quality sugar.

Juices clarified with activated paddy husk carbon were found to yield gur of better quality, with less of impurities and colour at the final stage.

Rab prepared from the clarified juice matured early and the yields of 1st sugar and 2nd sugar were considerably higher than that obtained from rab prepared by the indigenous method.

Even water clear juices obtained by active carbon filtration, were found to develop colour at the final stage of *gur* boiling. One aspect of the colour problem, *viz.*, the development of colour in sulphitation sugars obtained from coloured canes, was thoroughly studied. The bodies responsible for colour production in sulphitation sugars were identified as the anthocyanin pigments and a practical solution of the problem on factory scale was successfully carried out.

It was established that in the Open Pan Method of *gur* manufacture, with the gradual inversion of juices, with the high temperatures obtained, certain non-sugars interact with the reducing sugars and developed colours. Work was in progress to find out the nature and extent of the non-sugars present in carbon clarified juices, and responsible for colour development; and for the elimination of these bodies by adsorption, precipitation, etc.

On the laboratory side, a systematic study of a few important varieties, grown under different climatic and soil conditions was in progress. During the course of work, it became necessary to standardise the methods for the estimation of sucrose, invert sugar, other mono- and di-saccharides and non-sugars, such as gums, pectins and colouring matters.

Keeping quality of *gur* was one of the items which was carefully studied. Jaggeries, with good crystal development and good macro-structure were found to keep better. A simple test for differentiating good and bad jaggeries by pore space measurements was developed.

The proper control of Open Pan conditions for good crystal development in *gur*, the elimination of colloids responsible for frothing and foaming in the Open Pan, etc. were some of the other problems under study.

2. ACTIVE CARBON PROCESS

The Agricultural Engineer to the Government of Bengal designed a furnace for the manufacture of activated carbon from paddy husk on a fairly large scale for use in the clarification of sugarcane juice in the Open Pan Method of sugar manufacture. It proved satisfactory and the cost of active carbon ready for use was Rs. 4-13-9 per maund or slightly less than one anna per pound. From ten maunds of good *dhunki* husk at four annas per maund a yield of three and a half maunds of finished carbon was obtained. The cost of coal was the heaviest item of expenditure and as the furnace was stated to work better with begasse, the cost of production would be much less than one anna per pound. Revivification of the spent carbon should still further lessen the cost of active carbon.

Several tests were carried out on the use of the active carbon in white sugar manufacture by the Open Pan process and the opinion was expressed that the use of the active carbon more than repaid its cost by the increased recovery of white sugar. With three sets of filter batteries, consisting of four buckets in each set, and using 1 maund 5 seers (92 lb.) of the active carbon for the clarification of the juice obtained from 100 maunds of cane, the cost of filtration per 100 maunds of cane worked out to six rupees. By the new carbon clarification process 7.05 maunds of white sugar was obtained, while

by the old clarification using *bhendi* juice and sodium bicarbonate a yield of 5.7 maunds of sugar per 100 maunds of cane was obtained.

A margin of Rs. 3-5-0 extra per hundred maunds of cane was left in favour of the carbon process of selling at Rs. 7 per maund of sugar. The following data extracted from the report of the Agricultural Engineer are of interest.

	By the new active carbon process		By the old process	
	Mds.	Srs.	Mds.	Srs.
Cane crushed	100	00	100	00
Weight of rab (cold weight)	10	16	10	20
Weight of 1st sugar (dry)	5	36	4	20½
Per cent sugar on rab	56	65	45	35
Per cent sugar on cane	5	9	4	76
Weight of molasses	4	32	5	15
Weight of 2nd rab	3	30	3	30
Weight of 2nd sugar (dry)	1	6	0	37½
Per cent 2nd sugar on rab	30	6	25	0
Per cent 2nd sugar on cane	1	15	0	94

The second rab by the old process could not be centrifuged as the cane was very old but in the active carbon process the second sugar from the same cane could be directly recovered without further treatment. The percentage of second sugar by the old sugar in the statement above is not what was actually obtained but is a derived figure representing the average that is usually obtained by the old process.

In regard to manufacture of *gur* by the active carbon method of clarifying sugarcane juice, the Agricultural Engineer to the Government of Bengal is of the opinion that compared with the other methods of *gur* manufacture, the active carbon method will not be a paying proposition unless people are willing to pay higher prices for a really good *gur*.

At the Imperial Agricultural Research Institute a furnace of new design (Type 1938) for *gur* and active carbon manufacture was erected. The total cost of constructing the furnace with brick and cement came to about Rs. 100. The furnace has several advantages. It accommodates both the manufacture of carbon and *gur* in a compact space 30 feet by 20 feet; permits the simultaneous operations of carbon and *gur* manufacture; provides for the better utilisation of the heat of the flue gases in digesting the husk char with alkali.

Further experiments were carried out in the laboratory of the Institute and at the U. P. Government Centre at Dudhli near Saharanpur, in the direction of lessening the cost of active carbon manufacture. By reducing the concentration of caustic soda solution to as low as five per cent and the introduction of self-ignition of the husk, utilisation of flue gases heat, the heat of the sun and by the substitution of various kinds of cheap fuel such as dry leaves, reeds and the like it has been found that the cost of production can be reduced to four pice and even to less than one pice per pound of finished carbon, depending on the nature of the materials employed.

Mr. M. L. Gupta, a Khandsari sugar manufacturer in Bulandshar District, spent over two months, learning and investigating the details of white jaggery and active carbon manufacture, at the Institute and also at the *gur* development centre of the United Provinces Department of Industries. He submitted a report in which he expressed the opinion that the cost of active carbon production was sufficiently lowered to enable the adoption of the process on the large scale in the Khandsari factory.

An additional line of investigation in the direction of reducing costs was on the revivification of used carbon. After thoroughly washing and drying in the sun and ignition in closed tubes from 1 to 3 hours used carbon can be restored to its original efficiency. *Gur* made with revivified carbon was as good as that made with the original active carbon. Experiments carried out at the Saharanpur Centre, showed that the same carbon could be effectively revivified and used four times. At each revivification the loss of carbon amounted on the average to 12 per cent of the original active carbon. After each revivification, the carbon was tested by juice clarification and *gur* manufacture with results as good as when fresh active carbon was used.

The cost of revivification per pound of carbon works out to one half of a pice or one eighth of an anna. Calculating the cost of original and revivified carbon and the number of times it can be used, the ultimate cost is reduced to two pice and less and at such a price active carbon can reasonably be expected to play a significant part in *gur* and sugar manufacture by the Open Pan and vacuum processes.

IV. GENERAL CONSULTATIVE AND ANALYTICAL WORK

The following samples were analysed and reported upon during the year :—

Soils.	.	.	.	.	.	.	.	.	.	.	57
Manures and fertilizers	.	.	.	.	.	.	.	.	.	.	16
Feeding-stuffs	.	.	.	.	.	.	.	.	.	.	2
Water	.	.	.	.	.	.	.	.	.	.	22
Sugarcane	.	.	.	.	.	.	.	.	.	.	121
Pre-milk and colostrum	.	.	.	.	.	.	.	.	.	.	151
Syrup and fruit juices	.	.	.	.	.	.	.	.	.	.	2
Tobacco and tobacco-tomato grafts	.	.	.	.	.	.	.	.	.	.	14
Potato tubers	.	.	.	.	.	.	.	.	.	.	25
Beeswax	.	.	.	.	.	.	.	.	.	.	3
Miscellaneous	.	.	.	.	.	.	.	.	.	.	7

Of the soil's examined, eleven were received from the Locust Research Entomologist, Karachi, and 18 from the Director, Lac Research Institute, Namkum (Ranchi). Three soils received from the Agricultural Chemist and Soil Physicist, Sakrand, were examined for their soluble salts by water extracts and alcohol displacement methods. The extraction of total salts by the latter method (alcohol displacement method) in case of *normal soil* was less, whereas in case of *saline soil* it was more than what was obtained by the water extract method. Four soils received from the Botanical Substation, Pusa, were analysed in order to find out if the differences in sterility observed in pigeon-pea could be assigned wholly or partly to soil differences between the Gorrhi and Orchard fields. The Gorrhi field where the Pigeon-pea Type 51 showed the least susceptibility to sterility had the least contents of available P_2O_5 and total nitrogen as compared to the three Orchard plots having pigeon-peas Types 51, 69 and 80. Although the contents of P_2O_5

and N in the Orchard plots were higher than those found in the Gonrhi field, the values were quite normal for Pusa calcareous soil type and as such could hardly account for the varying degree of susceptibility to sterility.

Of the manures examined, four samples of compost were received from the Director of Agriculture, Kashmir.

Sixteen samples of water collected from spring or Artesian wells were received from Bhahrein (Persian Gulf) through the Director of Agriculture, Punjab, and were examined as to their suitability for irrigation purposes. Two samples of well water received from the Superintendent, Agricultural Experimental Station, Baroda, were also examined as to their suitability for irrigation purposes.

For the Agricultural Section, 121 samples of sugarcane juice were analysed twice during the season in connection with the farm's variety test. On the whole, this year's crop matured earlier and was practically free from the attack of *Pyrilla*. The growth was stunted owing to scarcity of water. The purity of most of the varieties was more than 87 and in some it was as high as 90 or more. Sucrose content of juice varied from 15.5 to 21.0 per cent and invert sugar 0.04 to 0.57. Varieties Co. 331, 419, 431 and 433 attained average weight of about 1.5 lb. or more and yielded juices of more than 90 per cent purity and less than 0.1 per cent invert sugar. Co. 508 gave a juice having 23.5 brix, 21.09 per cent sucrose and 0.13 per cent invert sugar, the purity of juice being 89.7. Co. 445 and Co. 513 varieties were not promising.

Two samples of tobacco and 12 of tobacco-tomato grafts received from the Imperial Economic Botanist were examined for their nicotine content. In case of tomato leaves above graft, three contained no nicotine and one contained 0.17 per cent, in case of tomato leaves below graft one contained no nicotine and one 0.45 per cent. In case of tobacco leaves above graft and tobacco leaves below graft, all the six samples contained nicotine varying from 0.22 to 1.04 per cent.

Twenty-five varieties of potato tubers received from the Imperial Economic Botanist were analysed for their protein and starch contents.

Two samples of syrup received through the Agricultural Marketing Officer, Delhi, were examined and appeared to have been prepared from cane sugar solutions, artificially inverted, coloured and flavoured.

V. PROGRAMME OF WORK—GENERAL

The following is the skeleton programme of work drawn up for the Section for the next few years to be followed as facilities become available.

1. SOILS

(a) Comparative physical, chemical and microbiological studies on cultivated and uncultivated soils to ascertain the trend of pedogenic processes under the influence of climate and geology and the changes brought about by cultivation and cropping under irrigated and unirrigated conditions.

(b) Collation of data and preparation of a soil map of India.

(c) Nitrogen fixation and carbon and nitrogen cycles in soils.

(d) So far, a considerable amount of attention has been paid to nitrogen which is available easily and in unlimited quantity by chemical and microbiological methods. The question of soil phosphates, the supplies

of which are very limited has not received the attention it deserves. Different forms of phosphorous and its availability in different types of soils, such as alkaline, acid, ferruginous and laterite, will be studied.

2. SOIL IN RELATION TO PLANT

- (a) Different methods of cultivation in relation to crop yields.
- (b) Draught of bullock drawn implements.
- (c) Composition and nutritive value of crops as influenced by soil and fertilizer treatment.
- (d) Cereal crops in relation to soil nitrogen.

3. MANURES AND FERTILIZERS

- (a) Relative efficiencies of organic manures and mineral fertilizers in relation to moisture availability and soil composition.
- (b) Possibilities of increasing and efficiency of fertilizers as judged by recoveries in crops.
- (c) Comparative merits of organic and inorganic manures on crop quality for industrial and food purposes.
- (d) Varietal differences with regard to fertilizer requirements.
- (e) In view of the importance of organic matter to soils, the study of the relative importance of organic matter and nitrogen contained in manures and the factors that contribute to the stability and rapidity of the destruction of the organic matter of the manures.

4. METHODS

- (a) Investigation of sampling methods for soils and crops.
- (b) Comparative studies on analytical methods employed in soil, crop, fertilizers and food analyses, having regard to reliability, cheapness and rapidity. The relative merits of quick versus slow methods will also be studied.

5. UTILISATION OF AGRICULTURAL PRODUCE AND AGRICULTURAL WASTES

Every agricultural crop grown needs processing either for preservation or for sale and all produce and waste should be considered as potentially valuable material for industry and trade. The study of the scientific and economic questions involved in the utilisation of agricultural produce and agricultural wastes and the development, where possible, of methods within the ability of the farmer will be of considerable advantage to him. Examples of these are the preparation of jaggery or *gur* from sugarcane and the making of activated carbon from a waste product like paddy husk.

PROGRAMME FOR 1939-40

The major lines of programme for 1939-40 will be :—

- 1. Comparative studies on soils formed under different conditions of temperature, rainfall and evaporation.
- 2. Studies on carbon and nitrogen fixation in soils.
- 3. Investigations on the chemistry of sugarcane and manufacture of *gur*.
- 4. Investigations on sampling and analytical methods.

REPORT OF THE IMPERIAL MYCOLOGIST

(G. WATTS PADWICK)

I. DISEASES OF PLANTS

1. WHEAT

Trial's for developing varieties of wheat resistant to loose smut were started in 1936, and 40 varieties of wheat were supplied by the Imperial Economic Botanist for this purpose. The first results, obtained in 1938, indicated that six varieties were completely resistant to smut, one showed 0·4 per cent infected plants, and nine showed less than 25 per cent infection. The rest varied in susceptibility from 25 to 80 per cent.

During the current year all the previous season's varieties were given a re-trial, and 48 more were added and the experiments were conducted with the co-operation of the Imperial Economic Botanist. The results indicated the following facts :—

- (1) Of the six varieties found last year to be resistant, five have continued so, while selections made last year in varieties showing 0·4, 9·7 and 20·1 per cent susceptibility all proved resistant. There are thus eight resistant varieties.
- (2) Of the 48 additional varieties, 14 showed no infection this year, and two showed less than ten per cent infection.

Twenty-six of the most resistant varieties together with several others which though susceptible are commercially important, will be tested next year.

Experiments to develop varieties of wheat resistant to flag smut were started in 1937. Seed of 97 varieties was smeared with smut spores before sowing, and very heavy flag smut infection appeared in the crop (up to 88 per cent). Twenty-four varieties had no smut infection, ten varieties had less than five per cent, six between five and ten per cent, and the remainder over ten per cent.

For the current year's trials seed was selected from healthy plants from the previous year. Sixteen varieties showed no infection, 20 varieties showed less than five per cent, 20 between five and ten per cent, and the remainder over ten per cent. The heaviest flag smut infection was 38·3 per cent.

2. OATS

In 1935-36 seven varieties of oats were found to be completely resistant to smut, one showed less than ten per cent infection, and the rest ranged in susceptibility from 17 to 93 per cent. Single plant selections were made from most of the susceptible varieties and from all the resistant ones. In 1936-37 five varieties continued to show complete resistance, two which had appeared completely resistant the previous year showed 0·5 and 0·6 per cent infection, two of the others showed less than ten per cent infection and the remainder had 15 to 88 per cent smutted plants.

With the help of the Imperial Economic Botanist the work was continued this year. Selections were again made in all the five resistant varieties

and some of the susceptible ones and these were used in the season 1938-39. Four varieties continued to show complete resistance, one which had shown about 35 per cent infection previously also produced no smutted plants, and the remainder varied in susceptibility from 15.4 to 100 per cent. Plant selections were made for seed for the next season.

3. MAIZE

A species of *Pythium* isolated from maize plants showing signs of a severe attack of root-rot at Sabour (Bihar) was used to infest soil in which maize seeds were planted. The developing seedlings took infection and about 50 per cent were killed. The fungus was re-isolated from the roots.

Morphological studies are being made on this fungus.

4. SUGARCANE

The Scheme for Research on Mosaic and other Diseases of Sugarcane, financed by the Imperial Council of Agricultural Research, terminated on May 31st, 1939, and was replaced by a new scheme in which most of the effort will be devoted to the testing of sugarcane varieties for resistance to various diseases and to an intensive survey of diseases at selected places. The work done under the old scheme is published by the Council in the annual report and a brief summary only is given here.

Mosaic.—Perhaps the most interesting findings with regard to mosaic, apart from the fact that the disease causes a comparatively small loss of yield and no decrease in quality, are those concerning natural transmission and recovery from mosaic. It has been found that in various parts of Northern India natural transmission does occur, but only to a slight extent. *Aphis maidis*, known to be the insect vector in other countries, has actually been found colonizing at Gurdaspur (Punjab) on sorghum and on an indigenous thin reed-cane variety of sugarcane known as "Shakarchinya". A barley crop has been found infected with *Toxoptera graminum*, also a vector. At Gurdaspur a ratoon cane crop adjoining a sorghum crop infected with aphids showed 100 per cent mosaic at the side adjoining the sorghum but no infection at the other side of the field. The small amount of natural transmission is perhaps fairly well counteracted by the phenomenon of recovery—the production of disease-free canes from setts cut from infected canes—so that the actual rate of increase in mosaic in the crop grown year after year from a crop with a small amount of mosaic need not necessarily be very great. Experiment has in fact shown that highly successful results can be obtained by simply selecting setts from healthy canes in a very heavily infected crop. At Pusa selections were made from a crop of Co. 313 showing between 70 and 90 per cent infection. The crop raised from these selected setts showed only three per cent infection.

Fungus and bacterial diseases.—The main work centred around the testing of varieties for resistance to red-rot (*Colletotrichum falcatum* Went.), wilt (*Cephalosporium sacchari* Butler) and smut (*Ustilago scitaminea* Sydow). For resistance to red-rot and wilt 42 varieties were tested, and for resistance to smut, 65 varieties are now under test. Both red-rot and wilt developed poorly, the maximum distance of spread during the season from the point of

inoculation of the cane being 14 inches for red-rot and ten inches for wilt, as compared with four feet two inches and three feet four inches respectively for the same diseases last year. The results under the present year's tests are somewhat inconclusive, the difference between the most susceptible and the most resistant varieties being rather small.

As in the case of mosaic, highly successful control of smut has been obtained by roguing, and it has been found that by this method even a heavy infestation may be brought under control in one or two seasons.

At Delhi the incidence of top-rot (*Fusarium moniliforme* Sheldon) was rather high, one plot of Co. 313 having 20.8 per cent infection. Another plot of the same variety, however, showed only 13.7 per cent infection, and a third showed only 2.4 per cent. Infected clumps of varieties Co. 312, 313, 285 and 223 were marked and were weighed, but there was no indication of loss of weight due to the disease. The same was true of the variety "Surkha Saharanpuri" at Karnal.

A severe outbreak of bacterial red-stripe disease (caused by *Bacillus, rubrilineans*) which occurred at the Sugarcane Research Station, Risalewala (Punjab) gave an opportunity to study the reactions of 85 varieties to this disease. Infection as high as 33 per cent was found in some varieties.

5. LINSEED

Spores of the rust fungus (*Melampsora lini* (Pers.) Lev.) were found to germinate more readily in distilled water than in tap water. The optimal temperature for germination was found to be about 22°C, but germination occurred also at temperatures of 10°C. and 25°C.

A comparison was made between linseed rust collections from Pusa and Karnal. Spores from these separate collections were used to inoculate linseed type Pusa 21 and flax variety J. W. S. The Karnal rust showed very heavy infection on Pusa 21 and none on J. W. S., whereas the Pusa collection showed only moderate infection on Pusa 21 but in addition caused slight infection of J. W. S. The results indicate that there are two physiologic forms of *Melampsora lini* in India.

6. GRAM

Fusarium causing wilt of gram was studied, an effort being made to determine the relationship between this fungus and *Fusarium orthoceras* Opp. et Wr. var. *pisi* Linford, to which it appeared to bear a close relationship owing to the paucity of macrospores.

Both fungi were grown on the usual cornmeal soil inoculum which was used for infesting pots, which were planted with peas and gram. The peas failed to take infection by either fungus, and the gram was infected only by the gram wilt fungus. It is evident that the two cultures are different physiologically, but it is also evident that *F. orthoceras* var. *pisi* is not necessarily distinguishable by its parasitism on peas.

When it was found that parasitism was in itself not very helpful in making determinations, being apparently too dependent on experimental conditions, resort was had to another method. The fungus causing gram wilt clearly belonged to the section *Elegans*, and apparently to the sub-section *Orthocera*. A comparison of morphological characters of the gram wilt organism and all *Fusaria* of the sub-section *Orthocera* on Wollenweber's various media under varying conditions was made. The data are now being collated, but the inherent difficulties of classifying *Fusaria* make unusual caution in drawing conclusions an absolute necessity. Until the study has been still further developed, therefore, no opinion can be expressed as to whether the gram fungus should be regarded as a new species or as only a physiologic form of a species previously described.

An experiment was made on the effect of temperature on the development of gram wilt. Gram plants sown in *Fusarium* infested and uninfested sterilized and unsterilized soil were kept out of doors and in glasshouse chambers at different temperatures. Sowing was done on the 14th January 1939. The average air temperatures at 9.0 A.M. and 4.0 P.M. out of doors and in the four chambers during the various periods of the experiment, are recorded in Table I. In any series, rapid wilting took place after the first plant showed symptoms. The appearance of the first wilted plant therefore virtually marked the termination of the experiment for that particular series, and temperatures were not recorded further.

TABLE I

Morning and evening temperatures (centigrade) in gram wilt experiment

Series	Date of first appearance of wilting	Average daily temperatures from 14th January till 27th January 1939		Average daily temperatures from 28th January till 3rd February 1939		Average daily temperatures from 4th February till 13th February 1939		Average daily temperatures from 14th February till 11th March 1939		Average daily temperatures from 12th March till 19th April 1939	
		9 A.M.	4 P.M.	9 A.M.	4 P.M.	9 A.M.	4 P.M.	9 A.M.	4 P.M.	9 A.M.	4 P.M.
1 Out of doors)	No wilting	12.2	25.0	11.1	21.1	12.2	23.9	15.5	23.5	23.1	35.0
2 (1st Chamber)	11th March	15.0	24.4	14.4	23.9	16.4	24.9	17.0	24.4	...	...
3 (2nd Chamber)	13th February	15.5	23.0	15.0	22.5	16.5	24.0	...	...	...	...
4 (3rd Chamber)	3rd February	17.5	27.5	17.0	27.0	...	...	...	...	...	...
5 (4th Chamber)	27th January	21.1	32.2	...	...	...	...	...	...	...	...

The results clearly indicate that wilting is closely correlated with high temperatures, and another fact of considerable interest was that wilting was just as rapid and severe in unsterilized soil as in sterilized soil, indicating that biological antagonism was not operating.

The influence of temperature on development of wilt was confirmed in a replicated field experiment on the date of sowing of gram, conducted by the Imperial Agriculturist who kindly permitted fortnightly observations to be

taken on his plots. The final totals of wilted plants according to the date of sowing are given in Table II.

TABLE II

Effect of date of sowing on wilt of gram in the field

Date of sowing	Percentage of gram plants wilted
23rd September	3.7
30th „	11.5
7th October	2.6
14th „	1.8
21st „	0.1
28th „	0.0

There is thus an indication that late sowing (which means lower temperatures) is beneficial in reducing wilt.

A start was made in testing the resistance of gram types to wilt. Ten types were tested in pots. Of these, five types showed no wilting, while in the others the percentage of wilted plants varied from 37 to 88.

An experiment was conducted to determine the effect of a mercurial seed dressing on wilt and seed-rotting of gram caused by *Fusarium*. The indications were that while seed dressing gave some protection against seed-rotting it failed to reduce the amount of wilt.

Infection experiments conducted with a pycnidial fungus isolated from wilted gram plants reproduced the disease. The fungus produces symptoms similar to those of *Fusarium* wilt. The fungus differs from the Punjab gram blight fungus (*Mycosphaerella rabiei* Kovachevsky) in cultural characteristics and in spore shape.

7. PIGEON-PEA AND SANN-HEMP

Cross-inoculation tests were started in order to determine the true relationship between the *Fusaria* causing wilt of these two crops. In all these tests the fungi were grown in a sterilized mixture of 95 parts soil, five parts cornmeal, and 30 parts water for a period of about three weeks, after which they were used to inoculate sterilized soil in pots in which the seed was sown.

As a preliminary, a test was made of the pathogenicity to pigeon-pea of 12 isolates obtained from wilting pigeon-pea plants from Pusa, and isolates of *Fusarium vasinfectum* Atk. from cotton and sann-hemp plants, these two fungi being supplied through the kindness of Dr. B. N. Uppal, Plant Pathologist to the Government of Bombay.

In this first test, eight of the 12 isolates from pigeon-pea caused wilting, while two more isolates caused severe rotting of the seeds. Neither the cotton isolate nor the sann-hemp isolate provided by Dr. Uppal caused wilting. Full results are given in Table III.

TABLE III

*Wilting of pigeon-peas with isolates of Fusarium from pigeon-pea, cotton and sann-hemp **

Culture	Isolated from	No. of seeds sown	No. of seeds germinated	No. of seedlings wilted
F. 1	Pigeon-pea, Pusa . . .	36	35	0
F. 2	" " . . .	36	33	17
F. 3	" " . . .	36	26	0
F. 4	" " . . .	36	17	7
F. 5	" " . . .	36	36	32
F. 6	" " . . .	36	35	32
F. 7	" " . . .	36	35	27
F. 8	" " . . .	36	15	0
F. 9	" " . . .	36	8	0
F. 10	" " . . .	36	33	25
F. 11	" " . . .	36	34	32
F. 12	" " . . .	36	32	31
F. 25	<i>F. vasinfectum</i> Atk. from cotton (Uppal.)	36	36	0
F. 26	<i>F. vasinfectum</i> Atk. from sann-hemp (Uppal).	36	36	0
Control		84	77	0

The second test conducted was with isolates from sann-hemp for their pathogenicity on sann-hemp. In addition, a culture of *Fusarium vasinfectum* Atk. from the Centraalbureau voor Schimmelcultures, Baarn, Holland, was included. The results are given in Table IV.

TABLE IV

Wilting of sann-hemp with isolates of Fusarium from sann-hemp †

Culture	Isolated from	No. of seeds sown	No. of seeds germinated	No. of seedlings wilted
F. 13	Sann-hemp, Pusa . . .	36	36	0
F. 14	" " . . .	36	31	0
F. 15	" " . . .	36	36	0
F. 17	" " . . .	36	29	13
F. 18	" " . . .	36	35	11
F. 19	" " . . .	36	31	18
F. 21	<i>F. vasinfectum</i> Atk. (Baarn) .	36	35	1
F. 26	<i>F. vasinfectum</i> Atk. from sann-hemp (Uppal).	36	32	12
Control		48	41	0

[* Seeds sown April 30th, 1938. Final counts taken July 8th, 1938. Each isolate was used to infest six pots, each of which had six seeds of pigeon-pea, except the controls, of which there were 14 pots.]

[† Seeds sown May 26th, 1938. Final counts taken July 18th, 1938. Each isolate was used to infest six pots, each of which had six seeds of sann-hemp, except the controls, of which there were eight pots.]

The results indicate that three of the isolates of *Fusarium* from sann-hemp growing at Pusa could cause wilt, as also did the isolate sent by Dr. Uppal. The culture from Baarn caused only one plant to wilt; possibly if the experiment had been continued for a longer time (the plants were less than two months old on completion of the experiment) more plants may have wilted.

A third test was commenced on July 30th, all the Pusa isolates, together with Dr. Uppal's isolate from sann-hemp, being included in a test on both sann-hemp and pigeon-pea. The incidence of wilting is indicated in Table V.

The general level of infection in this third test, was somewhat lower than in the first two, but otherwise the reactions of the isolates on their own hosts remained unaltered except in one instance, culture F. 4 failing to cause wilt of pigeon-pea. The results with 11 pathogenic isolates of *Fusarium* indicate a rather high degree of specificity for sann-hemp and pigeon-pea.

TABLE V

*Wilting of pigeon-pea and sann-hemp with isolates of Fusarium from the two hosts **

Culture	Isolated from	No. of seeds sown	Pigeon-pea		Sann-hemp	
			No. of seeds germinated	No. of plants wilted	No. of seeds germinated	No. of plants wilted
F. 1	Pigeon-pea (Pusa) .	24	23	0	24	0
F. 2	" " .	24	20	7	24	0
F. 3	" " .	24	17	2	24	0
F. 4	" " .	24	24	0	24	0
F. 5	" " .	24	24	7	24	0
F. 6	" " .	24	24	8	24	0
F. 7	" " .	24	24	6	23	0
F. 8	" " .	24	24	2	23	6
F. 9	" " .	24	24	0	23	0
F. 10	" " .	24	24	6	22	0
F. 11	" " .	24	24	10	23	0
F. 12	" " .	24	24	9	23	0
F. 13	Sann-hemp (Pusa) .	24	24	1	23	1
F. 14	" " .	24	24	0	24	0
F. 15	" " .	24	24	0	24	0
F. 16	" " .	24	24	0	24	0
F. 17	" " .	24	24	0	22	8
F. 18	" " .	24	24	0	23	7
F. 19	" " .	24	24	0	23	11
F. 26	<i>F. vasinfectum</i> Atk. from Sann-hemp (Uppal).	24	24	2	23	7

[‡ Seeds sown 30th July 1938. Final counts taken 27th September 1938. Each isolate was used to infest four pots of pigeon-pea and four pots of sann-hemp, each of which had six seeds.]

A great deal of taxonomic work has also been done with these isolates, but the results will remain in abeyance while completing the study together with that of 32 selected cultures of *Fusarium* since isolated from cotton, sann-hemp and pigeon-pea. The final conclusions will thus rest on a study of over 50 cultures representative of a total of approximately 380 isolates.

8. TOBACCO

Experiments in the transmission of tobacco leaf-curl by white-flies (*Bemisia gossypiperda*) fed on juice of infected plants only met with partial success. Out of 150 plants on which white-flies from infected plants were placed, none showed typical leaf-curl symptoms, though 11 showed vein clearing, five of these showing a near approach to leaf-curl.

9. CINCHONA

An experiment was started at Munsong in March to try to find the cause of the seedling disease of cinchona. Seeds were sown in soils infested with three different isolates of *Fusarium* suspected of causing the disease and seedlings were transplanted into similarly infested soil. Experiments were also laid down in which one-year-old seedlings were inoculated with *Fusarium* after damaging the bark. Up to the present time (end of June) there is no sign of infection having taken place by any of the methods used. During the visit many diseased plants were collected and from these isolations were made. In the great majority of cases species of *Fusarium* were obtained in culture.

10. BETEL-VINES

An examination was made of betel-vine (*Piper betel*) gardens in the State of Chhatarpur (Central India), from where complaints were received of severe root-rot or wilt. It was hoped that as a result of a systematic survey some clues as to the predisposing factors might be obtained, but most of these were of a negative nature. In all the villages visited there were some gardens showing severe damage and others showing practical freedom from disease. Also, there appeared to be no relationship between age of the plantation and incidence of disease. The growers were not particularly informative as to the treatments given to the soil, but it appeared that more or less the same kind of treatment was given throughout, name'y, replacement of the top soil to a depth of a few inches by a mixture of ordinary soil of the vicinity, sand, *til* (*Sesamum indicum*) cake and sometimes *til* oil. The soil in the district is of a rather clayey nature and at the time of inspection the surface of the soil was wet and sticky. During the monsoon it is probably waterlogged.

Isolations were made from various pieces of tissue collected in six of the gardens examined. The isolates obtained were almost entirely *Colletotrichum* sp. and *Fusarium* sp. Table VI summarises the isolations obtained from stipules, stems, leaves and roots of the affected plants.

TABLE VI

Distribution of Colletotrichum sp., Fusarium sp. and other fungi in the tissues of diseased betel-vines

Tissue	Number of isolates of <i>Colletotrichum sp.</i>	Number of isolates of <i>Fusarium sp.</i>	Number of isolates of other fungi	Number of pieces used for isolation
Stipules . . .	10	25	0	40
Stems . . .	19	7	0	30
Leaves . . .	4	1	2	10
Roots . . .	1	17	1	30

Thus out of 87 growths, 34 proved to be *Colletotrichum sp.*, 50 were *Fusarium sp.*, and there were only three other fungi. *Fusarium* was abundant in the roots as well as in the stipules, where it was first observed, and *Colletotrichum* was obtained not only from the roots and stems, where it was fruiting abundantly, but also from leaves and stipules and even in one case from the root. There were several species of *Fusarium*. Neither *Phytophthora* nor *Rhizoctonia* was isolated, though the former was observed in sections of some leaves.

11. BANANAS

Suckers of bananas were received from the Deputy Director of Agriculture, Cuttack, Orissa, with the complaint that premature decaying of the plants was occurring over large areas. Histological examination gave strong indications that the disease is the destructive virus disease known as "bunchy top" which causes havoc in Australia, Fiji, Ceylon, Egypt, the Philippines and elsewhere.

12. CITRUS

As reported last year, a species of *Fusarium* was found to be fairly regularly associated with the decaying roots of orange trees. This species, and a number of other isolates, were used to infest sterilized soil into which seedlings of sweet limes and *jamberi* stocks about six months old were transplanted in September 1938. Up to the time of writing (July 1939) no sign of damage can be found on the plants, which are now one to two feet high and are bushy and healthy. Another experiment was started in February in which seedlings of oranges only a few weeks old were used. These also, after four months, appear to be quite healthy.

II. FRUITS AND VEGETABLES IN DELHI MARKET

The practice of visiting Delhi fruit and vegetable markets fortnightly was continued throughout the year.

During the year, rotting of apples was found to vary from one per cent to 50 per cent. The indications are that rotting organisms enter through wounds. From August to October the main damage was due to *Aspergillus sp.*, but after November it was caused mainly by *Penicillium*. In addition to these two main rots, *Rhizopus sp.* and *Cladosporium sp.* were sometimes found associated with rotten fruits. Apples from Bannu (N.-W. F. P.), Multan

(Punjab) and Saharanpur (U. P.) showed as many as 80 per cent of the fruits attacked by scab, the fungus being present in the *Fusicladium* stage. Apples imported from Japan, Australia and America were practically free from damage.

The pear rotting disease referred to in the previous report was found to be due exclusively to attacks of *Aspergillus japonicus* Saito. Losses up to 20 per cent were observed.

The chief loss of Nagpur oranges was that due to *Penicillium digitatum* Sacc. and to a lesser extent a species of *Aspergillus* in the early crop, received from September to January. The rot found in the later crop, received from December to May, showed a smaller amount of damage which appeared to be of fungal origin associated with secondary bacterial infection.

Lemons (*Quagzi* lime, a variety of *Citrus medica*) are obtained locally and from the Central Provinces, Madras, Bengal and Bombay. Large numbers of these fruits suffered severely from bacterial canker. The consignments from local gardens and the Central Provinces were particularly badly affected.

Grape fruits from Jaffa (Palestine) were quite free from disease.

Pomegranates were found to be almost free from diseases unless they had been damaged in packing, in which case common moulds usually gained entrance.

Mangoes may be obtained in Delhi Markets throughout the year but the important season is only June and July, when the crops arrive from the United Provinces and Bihar. All consignments of ripe fruits were found to contain a few mangoes suffering from a rot caused by a species of *Dothiorella*.

Several kinds of melons are sold in considerable quantities. Musk melons, from Lucknow, invariably appeared healthy. Large numbers of water melons, which come from Farukhabad (U. P.), were found to arrive in a damaged and rotten condition due to careless methods of transport, the fruits being simply hauled in wagons without the use of any kind of packing material. "Sarda" melons sometimes showed soft spots caused by a species of *Fusarium*.

Pineapples from Sylhet, Assam and Singapore showed a certain amount of rotting caused by *Ceratostomella paradoxa* (de Seynes) Dade.

Bananas generally come from Bombay in a green condition. Only when on rare occasions they were found over-ripe was there any sign of rotting.

While American grapes arrived in perfect condition, those arriving from Indian grape-growing districts frequently showed shedding of berries from the bunch. A slight blackish discoloration of the fruit at the stalk-end was found to be due to growth of yeasts, bacteria and moulds.

Cherries from the North-West Frontier Province were covered with a mouldy growth of *Acrothecium lunatum* Wakker.

Less attention has so far been paid to vegetables, as these are largely locally grown and the financial losses in packing, transport, etc., are less serious even in cases where the damage is heavy. Several vegetables do, however, show considerable damage, notably potatoes, which suffer from dry and wet rots, chillies from pod-spotting and onions and tomatoes from bacterial rotting.

Four facts of very considerable significance have emerged from these surveys :—

(1) The degree of fruit spoilage in imported fruits, such as apples from Australia, America and Japan, and grapes from America is far lower than the spoilage in the corresponding Indian produce.

(2) Spoilage in many cases appears to originate from damage caused to fruits prior to or during transport. For example, it is almost always possible to trace the point of origin of rot in apples to a tear on the skin, in pears to an insect puncture, in oranges to a thorn mark and in water-melons to a crushed skin.

(3) Fruits from certain districts shew fairly regularly a higher degree of damage than those coming from other districts.

(4) The losses are frequently very great, instances having been observed where the entire consignment of fruit was rotten.

It seems that there are some instances where the provinces might very profitably consider a thorough examination of the whole problem of fruit marketing with the object of reducing the continuous loss of income to the growers and foodstuffs for the consumers. Losses of this sort are far more serious than losses due to diseases in the field, for they do not end with a mere reduction of out-turn. Costs of picking, packing, and transport are the same for fruits which eventually arrive rotten as for those which reach the fruit dealer in healthy condition. Furthermore, the effect of receiving frequent consignments of fruits in poor conditions eventually results in discontinuation of orders. While a further period of survey is necessary before details can be given, there is little doubt that no more profitable field of endeavour in marketing is to be found than in the marketing of Indian fruits.

III. SOIL CONDITIONS IN RELATION TO DISEASE DEVELOPMENT

A line of study to which considerable attention has been devoted is that of the survival of pathogenic fungi in the soil, with special reference, at the present moment, to biological antagonism. In this respect, a number of pathogenic soil-borne fungi and some common soil saprophytes have been selected. Preliminary experiments were made in Petri dishes, where species of *Cephalosporium* and *Trichoderma* have shown antagonistic action against a number of important soil parasites. These preliminary experiments are now being followed by pot culture experiments. Various experiments have also been arranged to study the period of survival of plant parasitic fungi in the soil under different cultural and manurial conditions. Interesting results of a preliminary nature have been obtained.

IV. TAXONOMY OF SMUT FUNGI

Work on taxonomy of smuts of sugarcane was brought to a close, and the results of the work have been submitted for publication. Seventy-three culminicolous smuts collected in India, Burma, Java, China, the Philippines and Mauritius were examined and the conclusion reached was that the smut on cultivated sugarcane is caused by one species and two varieties. *Ustilago scitaminea* Syd. is already known and is of wide distribution in India. *U. scitaminea* Syd. var. *Sacchari Barberi* Mundkur occurs in Eastern and Northern

India but is absent from Western and Southern India. It also occurs in Mauritius. The principle sugarcane smut in China and the Philippines seems to be a second variety *U. scitaminea* Syd. var. *Sacchari officinarum* Mundkur, which was collected in India also in 1908.

A large amount of work on the taxonomy of Indian smut fungi has been in progress during the year. A first article on this work has now been published. Forty-four collections were critically re-examined and the identity of the hosts was checked and corrected where necessary. There were found to be 25 species, of which seven were new species and five were new combinations. The new species were the following :—

<i>Sphaceotheca Sahayai</i> Mundkur	on <i>Dicanthium annulatum</i> (Forsk.) Stapf.
<i>Ustilago Barberi</i> Mundkur	on <i>Cym bopogon coloratus</i> Stapf.
<i>Tilletia Ajrekari</i> Mundkur	on <i>Pennisetum typhoides</i> Stapf.
<i>Sphacelotheca Dinebrae</i> Mundkur	on <i>Dinebra retroflexa</i> Panzer.
<i>Sorosporium Azmatii</i> Mundkur	on <i>Chrysopogon coeruleus</i> (Steud.) Watson.
<i>Sorosporium Penniseti</i> Mundkur	on <i>Pennisetum ciliare</i> Link.
<i>Ustilago Polytocae</i> Mundkur	on <i>Polytocha barbata</i> Stapf.

V. MISCELLANEOUS

Specimens supplied from the herbarium to workers in various parts of India and abroad numbered 101 and living cultures supplied numbered 55. Two hundred and seven specimens were added to the herbarium and 200 to the living culture collection.

Work was undertaken in co-operation with the Sugar Technology Institute, Cawnpore, to study the spoilage of sugar by moulds and bacteria. Twenty-four cultures were obtained from sugar, some consisting of mixtures which had to be purified. The majority of these have now been identified with valuable help from the Imperial Mycological Institute, Kew, to whom thanks are due.

A list of new plant diseases recorded in India during 1938 was sent to the International Institute of Agriculture, Rome. The International Institute was also provided with information on the present organisation in India for the control of the diseases and pests of horticultural crops and on legislative and administrative measures prescribed in the country since 1937 relative to the import and export trade in horticultural crops as regards plant protection.

Aeroscopic slides were exposed for the Officer-in-charge of the Imperial Council of Agricultural Research Scheme for Investigations on Cereal Rusts, Agra.

A list of specimens in the Herbarium Cryptogamae Indiae Orientalis has been prepared, and it is hoped that this may be printed in the near future.

Annotated bibliographies on mycological or pathological problems were supplied to the following persons :—

- (1) Government Mycologist, Burma.
- (2) Research Assistant Mycologist, Government Fruit Research Station, Chaubattia (U. P.).
- (3) Professor of Botany, Royal Institute of Science, Bombay.
- (4) The Medical Supply Concern Ltd., Calcutta.
- (5) The Economic Botanist, Government of Bengal.
- (6) The Registrar, Co-operative Societies, Holkar State.
- (7) The Assistant Mycologist, Punjab Agricultural College, Lyallpur.
- (8) Senior Marketing Officer, Imperial Council of Agricultural Research.

The Director of Agriculture, Government of H. E. H. the Nizam of Hyderabad, was given advice on the detailed programme of work on plant diseases being undertaken by the Department of Agriculture of that State.

Specimens were examined, and technical advice was given, in 85 cases of disease out-breaks.

VI. PROGRAMME OF WORK FOR 1939-40

1. Continuation of work on varietal resistance of cereals to smuts, Modes of infection of crop plants with smuts. Completion of taxonomy of Indian smuts.

2. Fruit and vegetable diseases—continuation of survey in Delhi Market.

3. Diseases due to *Fusarium*. Identification of species. Selection of varieties of gram and pigeon-pea resistant to wilt.

4. Study of soil conditions favouring development of *Fusarium* root-rots and wilts.

5. Flax rust. Identification of physiologic forms.

6. Bananas. Determination of the disease suspected of being bunchy top. Study of its incidence.

7. Leaf-curl of tobacco—further attempts to transmit by infected juice.

8. Testing of sugarcane varieties for resistance to smut, red-rot, and wilt. Intensive disease surveys in sugarcane experimental stations.

9. Potato blight and tuber rot caused by *Phytophthora* Sp.

10. Potato storage rots—isolation of organisms.

11. Canker disease of pigeon-pea—etiology.

12. Virus diseases of tomato.

13. Collection and identification of specimens, identification of fungi received in culture, and development of herbarium and culture collection.

REPORT OF THE IMPERIAL ENTOMOLOGIST

(HEM SINGH PRUTHI)

I. GENERAL

The main functions of the Entomological Section, in addition to research work on problems of all-India importance are the building and maintenance of collections of insects associated with agriculture in different parts of India, keeping relative records of the incidence of major pests in various parts of the country, identification of specimens received from provincial entomologists and other workers and giving the general public advice about the control of insect pests. A number of students are also admitted every year for a regular post-graduate course or for training and research in special aspects of entomology.

Survey work on the desert locust in North-West India, which had been in progress under a scheme of the Imperial Council of Agricultural Research since 1931, was taken over by the Government of India from 1st April 1939 and put in the charge of the Imperial Entomologist. A small locust warning organization has been established on a permanent basis. The staff is distributed all over the desert tracts of Rajputana, Sind and Baluchistan, there being about one dozen principal observation outposts in various regions. Locusts do not observe international boundaries. The Imperial Entomologist has, therefore, to keep himself in close touch with locust movements in the neighbouring countries, *e.g.*, Iran, Arabia, Mesopotamia, Africa, etc.

II. SPECIAL INVESTIGATIONS

1. ECOLOGY OF SPOTTED BOLLWORMS (*EARIAS* spp.) OF COTTON AND THEIR IMPORTANT PARASITES

The study of the fecundity and development of the pre-imaginal stages of *Earias fabia* and its parasite, *Microbracon lefroyi* (D. & G.), was closely studied under certain constant temperatures and humidities. The work carried out so far points to the following conclusions.

Theoretically, the thresholds of development of the host as well as of the parasite lie at about 12°C., but in the laboratory, long continued exposures to a temperature of 13°C. or below, prove fatal to both the species. There seems to be little foundation for the common belief, therefore, that severe winters are more injurious to the parasite than to the host. The upper vital limit of the host lies at about 40°C. and that of the parasite a little above 35°C. While a constant temperature of 40°C. is fatal to all the stages of the parasite, it allows some development of the host, particularly in its larval stages. Likewise, even exposures of about 12—18 hours to 40°C. or more than 4 hours to 45°C. kill the pre-imaginal stages of the parasite, but have no effect on those of the host. Thus, temperatures between 35° to 45°C. and the duration for which they prevail in nature, are important factors determining the host and parasite populations. At the various temperatures tried within the vital limits, *viz.*, 16°, 20°, 25°, 30° and 35°C., the parasite developed two to two and a half times faster than the host and thus had a marked advantage over the latter.

Whereas the viability of *E. fabia* eggs is lowered with the fall of temperature, that of the parasite eggs is not affected. The larval viability of the parasite (59—74 per cent), although to some extent dependent on temperature, always remains markedly higher than that of its host larvae (11—14 per cent) which undergo a high mortality in the first instar. Due to this factor also the host is greatly handicapped in its power of multiplication. The pupal viabilities of the host as well as of the parasite are not much affected by temperature between 16° and 30°C. Above this range, temperatures, say near 35°C., are decidedly detrimental to the viability of the parasite but not so to that of the host.

With regard to moisture, the larval stage of the host is the only stage requiring saturated atmosphere for development, living as it does inside the plant tissue; the eggs and pupae develop best at a saturation deficiency of 3 mm. The parasite, on the other hand, passes two of its important pre-imaginal stages, *viz.*, egg and larval, under the saturated atmosphere of the plant tissue, and is, therefore, highly sensitive to drought. For the pupal stage of the parasite, which is the only stage capable of standing some desiccation, an almost saturated atmosphere is ideal for development as well as viability.

In nature large numbers of flower buds and bolls of cotton, infested with bollworms, fall to the ground and dry up, thus creating a dry environment for the bollworms and the parasite grubs living therein. The latter being incapable of moving from one host larva to another, are dependent for the completion of their development on atmospheric humidity, which, if sufficiently high, can alone keep the paralysed host in a condition suitable for feeding by the parasite grub. It is well known that during years of good rain the bollworms are not serious on cotton and the cause of this is solely ascribed to the mechanical action of rain in shaking off attacked buds, etc., and drowning the bollworms. The present studies, however, indicate that it is not the mechanical effect of rain which is beneficial, but that summer rains help in controlling the pest by lowering the temperature which is beneficial to the development and viability of the parasite and by raising the humidity which is injurious to the host. High temperatures and low humidity during summer are probably the chief factors which cripple the parasite's population so severely that it may remain insignificant even during autumn, the period when conditions are usually optimum for its rapid development. The few individuals which might be present are further affected by winter, the more so if it is severe, but not necessarily more injuriously than their host. This results in a considerable decrease in the population of the parasite and hence acts as an important cause for a serious epidemic of the bollworm on the next cotton crop.

The development and fecundity of *Melcha nursei* Cam., an important Ichneumonid parasite of the pupae of *Earias* spp., was also studied at constant temperatures of 25°, 30° and 35°C., and different saturation deficiencies.

The incubation period was found to be 24—28 hours and 20—24 hours at 25° and 30°—35°C. respectively, the larval period was four days and three days and the pupal period 10-11 days and 7-8 days at 25° and 30°C. respectively. Larvae and pupae of this parasite failed to develop at 35°C.

As many as 121 pupae were paralysed by a single female, which laid 164 eggs on them. The maximum oviposition at 35°C. was only 55 eggs on 46 pupae.

More than 90 per cent of the emerging adults at the higher temperatures were males ; the cause for this preponderance is still unknown. Males were always observed to be with the females and they were seen to copulate as well occasionally.

2. INSECT VECTORS OF TOBACCO LEAF-CURL DISEASE IN NORTH INDIA.

This disease was only known to be of common occurrence in North Bihar and certain parts of the United Provinces, but during March 1939 it was also observed by the Imperial Entomologist at Sakrand in Sind where the incidence was fairly high. We had also specimens of diseased plants from Baroda. These observations indicate that leaf-curl is widely distributed in the Indo-Gangetic region. In the last year's report, as a result of extensive experiments carried out during 1936-38, it was shown that the white-fly, *Bemisia gossypiperda*, is the most important vector of this disease in North Bihar, that sann-hemp and *Ageratum conyzoides* are important alternate hosts of the leaf-curl virus, and that the white-fly can easily transmit the disease from the alternate hosts to tobacco and *vice versa*. During the year under report the above results were confirmed and several other plant hosts of the white-fly, which showed symptoms reminiscent of tobacco leaf-curl disease, were experimented with to determine which of them could serve as additional alternate hosts of the virus. As a result of several large series of experiments it has been found that the white-fly can transmit the disease from several other plants to tobacco. The main results of various experiments are summarized in the following table :—

Main results of transmission experiments

Zinnia elegans to Tobacco

Series	Time of experiment	Age of tobacco infected (weeks)	No. of plants infected	No. of plants which developed disease and its types	Percentage of successful transmissions
I	10th/11th September 1938	8½	4	3	75
II	8th November 1938	8	15	13	87
III	7th/8th December 1938	8	15	7	47
IV	5th/7th January 1939	8	6	5	83

Solanum nigrum to Tobacco

I	22nd/26th July 1938	10	17	16	94
II	4th/5th August 1938	7	1	1	100
III	11th October 1938	8	12	..	..
IV	9th November 1938	8	15	1	

Euphorbia hirta to Tobacco

I	25th July 1938	10	9	6	67
II	25th/26th July 1938	6	9	2	22
III	23rd August 1938	10	10	Nil	Nil
IV	1st/3rd September 1938	7	12	Nil	Nil
V	6th/7th October 1938	8	10	Nil	Nil

Main results of transmission experiments—contd.

Series	Time of Experiment	Age of tobacco infected (week)	No. of plants	No. of plants which developed disease and its types.	Percentage of successful transmissions
<i>Vernonia cinerea</i> to Tobacco					
I	5th/7th September 1938.	8	12	2	17
II	10th/11th October 1938 .	8	12	<i>Nil</i>	<i>Nil</i>
III	6th/7th November 1938 .	8	15	<i>Nil</i>	<i>Nil</i>
IV	11th/14th December 1938	9	15	<i>Nil</i>	<i>Nil</i>
V	2nd/3rd January 1939 .	7½	15	1	7
VI	7th/8th February 1939 .	8	15	4	27
<i>Lycopersicum esculentum</i> to Tobacco					
I	7th/9th January 1939 .	8	10	2	5
II	10th/11th February 1939	8	16	7	44
III	29th/30th March 1939 .	11	25	1	4
<i>Launea asplenifolia</i> to Tobacco					
I	2nd/3rd September 1938	7	6	1	17
II	10th January 1939 .	8½	6	<i>Nil</i>	<i>Nil</i>
III	12th/13th February 1939	9	10	5	50
<i>Sida rhombifolia</i> to Tobacco					
I	3rd/4th September 1938	7½	12	4	33
II	12th/13th October 1938 .	8	12	<i>Nil</i>	<i>Nil</i>
III	7th November 1938	8	15	1	7
IV	13th/14th December 1938	9	15	1	7
V	4th/5th January 1939 .	7½	15	3	20
VI	8th/9th February 1939 .	8	15	5	33
<i>Sida humilis</i> to Tobacco					
I	4th/5th September 1938 .	8	11	5	45
II	14th/15th October 1938 .	9	12	<i>Nil</i>	<i>Nil</i>
III	6th November 1938	8	15	1	7
IV	18th/19th December 1938	9½	15	1	7
V	5th/7th January 1939 .	7½	4	<i>Nil</i>	<i>Nil</i>
VI	8th/9th February 1939 .	8	5	1	20

In addition to the above, the following plants were experimented with to ascertain if they were also alternate hosts of tobacco leaf-curl; some positive transmissions were obtained, but the results are yet inconclusive:—

Hibiscus esculentus

Duranta plumieri

Nicotiana plumbaginifolia

Scoparia dulcis

It may be added that none of the controls under the various series developed leaf-curl.

It was found that even one individual could transmit the disease. The minimum period tested for which the white-fly was fed on the diseased source and successfully transmitted the disease to tobacco was one hour.

A survey of the food plants of the white-fly was continued and, during the year under report, this species was found feeding on about 75 plants, a great majority of which showed some curling of leaves. However, it has yet to be ascertained which of them harbour tobacco leaf-curl virus. The following natural orders were represented among the food plants :—

Solanaceae (17 spp.), Leguminosae (15 spp.),

Compositae (19 spp.), Malvaceae (8 spp.),

Cruciferae (7 spp.), Cucurbitaceae (7 spp.),

Labiatae, Urticaceae, Euphorbiaceae, Amarantaceae, etc.

From the foregoing, it will be obvious that there are numerous alternate hosts of the virus or viruses causing leaf-curl in tobacco. Therefore, the method of controlling the disease by the eradication of alternate host plants, as advocated in Africa and Java, does not seem to be of much practical importance in North India. I am doubtful if this method is completely successful even in the countries named above, because, as the available literature indicates, all the alternate hosts of the white-flies concerned in those countries do not seem to have been investigated.

The other method of controlling the disease is by protecting the crop against infestations of the white-fly. The work carried out during the last three seasons on the incidence of leaf-curl at different times of the year shows that the maximum incidence of the disease is in the autumn, indicating thereby that the infection of the crop takes place sometime in September. At this time the crop is either still in the nurseries or has been recently planted in the field. Some preliminary spraying and dusting experiments have been carried out during the year under report with encouraging results. They will be repeated on a large scale next year and their results reported in due course.

The bionomics of the white-fly, its life and seasonal history and its incidence at different times of the year have also been studied. There are more than half a dozen broods during July to November when the species is most common in the fields. It is again active during spring, but its population considerably decreases in the hot weather.

3. PESTS OF FRUITS AND VEGETABLES

The study of the insect pests of fruits and vegetables has been continued at New Delhi as well as in certain other parts of India. In the North-West Frontier Province the fruit-fly, *Dacus ferrugineus* Fabr., was again found to be a major pest of several fruits, e.g., peach, pear, guava, loquat, apricot, etc. Its life-history, biology, and chemotropic responses were further investigated and, during the year under report, several additions to our knowledge of this pest were made.

At Kohat the incidence of this fruit-fly in guava orchards ranged from 5 to 26 per cent in August to 70 per cent in September, but in pear orchards at Tarnab the percentage of infestation in September was only 4—8. An interesting feature of the collections of the fly made in the orchards, as well as those reared in the laboratory, was the enormous range of colour variations in them. Of the three colour forms, namely 'light' forms, 'dark' forms and forms intermediate between these two, the last named form was found to predominate in the field. These colour forms are so marked that it was

suspected that they might represent distinct varieties, but, after reference to a specialist, it is decided to regard all the three forms at present occurring in North-West India, as *D. ferrugineous*. Newly emerged flies of this species were successfully bred in captivity by feeding them with an aqueous solution of different combinations of bacto-peptone, yeast powder and sugar. The maximum number of eggs laid by a female in captivity was 213 within a period of 31 days. Flies emerging in October could be kept alive throughout the winter. It seems that the survival of the flies as well as their egg-laying capacity is affected by the nature of the feeding solution.

Trapping of flies with clensel, pollard and citronella baits was tried on a much larger scale than last year. One hundred and seventy-two traps baited with the lures were used. The traps devised by us and made locally at Rs. 1-14-0 per dozen, as compared with glass-bottle traps supplied by "Clensel Works", Howrah, at Rs. 6 per dozen, were found quite satisfactory. The formulae for the two baits are: (i) Clensel 1 pt., water 20 pts. (ii) Wheat bran 8 oz., commercial borax 8 oz., water one gallon (pollard bait). With these baits, 50—60 per cent of the fly catches consisted of females, many of them being in gravid state. Regarding the citronella bait, it was found that if used at the rate of 1 drop to 1 ounce of sugar solution it attracted a very large number of males but very few females. Comparatively lesser number of flies were attracted to a lower strength (1 drop to 10 ounces), but they included proportionately more females.

The experimental varieties of safflower in the plots of the Imperial Economic Botanist were found suffering heavily from the attack of the fruit-fly, *Acanthiophilus helianthi* Rossi, both the genus and species having been unrecorded from India so far. The new pest was studied closely. The varieties, Nos. 11—15, 20—22, 30 and 34 were seriously infested, the average in the last two varieties ranging from 50 to 62 per cent. The female fly lays eggs in punctures in the involucre of the flower-heads and the maggots feed on the florets and even bore into the thalamus. The infested bud rots and consequently an odorous juice oozes out of it and gives it a damp appearance. The maggots pupate in the buds and the fly completes three generations during the season (March to May). The duration of the various stages in the laboratory, with a temperature range of 78·5° to 82·5°F., was: egg 25 hours, maggot and pupa, 7 days each. Adults could be kept alive in captivity for about 10 days by feeding them with peptone, yeast and sugar. One male fly lived as long as five weeks. The biology of this new pest will have to be investigated for another one or two seasons before suitable control measures can be devised.

4. STUDIES ON INDIAN PARASITES

The growing importance of controlling insect pests by means of their natural enemies has made it necessary to have as complete a record as possible of the parasites and predators, attacking various insects in the field in different parts of the country. Such records can only be useful if they give accurate and up-to-date information about the hosts, localities and seasons of the year during which the parasites have been reared. Furthermore, it is essential that the parasites are correctly identified so that the worker, who is assessing their potential value, may be able to gather all information on them available in literature.

During the year under report complete data available on the biology, hosts and distribution of parasitic Chalcidoidea known from India, were collected. The main source of information was the record of notes kept in the files of this Section for a long time, but recent observations made by the members of this Section personally and by provincial workers were also incorporated. This work involved proper sifting of the data and careful checking to bring the results up to date and an illustrated bulletin on the subject is now in press. In this way a great body of useful information is made available to all entomological workers both in India and abroad, which was previously either locked up in laboratory records or formed part of miscellaneous notes of individual workers.

Systematic work on certain groups of parasites has been carried on in the Section since the last few years. During the year under report, a large collection of parasites of sugarcane pests was examined and identified. The material consisted of over 25 species belonging to Chalcidoidea, Proctotrypoidea, Braconidae and Ichneumonidae, some of the species being new to science. Interesting species in this collection include :

Two new egg-parasites of *Pyrilla*, viz., *Agéniaspis pyrilla* Mani and *Cheiloneurus pyrilla* Mani ;

Trichogramma intermedium How., bred from the eggs of *Danaïis liniace* *Argyria sticticraspis*, *Scirpophaga* spp. and *Emmalocera depressella*, and recorded for the first time from India ;

Atritomellus indicus Mani, parasite of the nymph of the Neuropterid *Nimboa basipunctata* ;

Mesostenoides clavinervis Cam. (Ichneumonidae) and a new species of *Rhaconotus* parasitising larva of *Scirpophaga* sp. ;

Phanerotoma hendecasisella Cam. (Braconidae) parasitising larva of *Emmalocera depressella*.

Some specimens ' parasitic on case-worms on sugarcane ' were identified as belonging to *Cedria*, a Braconid genus doubtfully placed under the sub-family Pambolinae : the present specimens, however, come nearer an allied sub-family Hecabolinae, and were interesting in indicating the affinities of the two sub-families and the position of *Cedria* with respect to them.

Two parasites, *Microbracon lefroyi* (D. & G.), attacking spotted bollworms of cotton, and *M. greeni* (Ashm.), attacking the larvae of *Eublemma amabilis*, hitherto regarded as two distinct species, were found on close study to be identical in structure, though differing in some points of their biology. They have, therefore, been synonymised and the former made a biological race of the latter. Another species of *Microbracon* parasitising caterpillars of *Antigastra catalaunalis* in Delhi, has been under examination and was identified in this laboratory as *M. brevicornis* Weism. and as *M. hebetor* Say by the Imperial Institute of Entomology, London. It seems that *brevicornis* and *hebetor* are not synonymous, and in view of the economic importance of the latter species specially in relation to the lac insect, the correct identity of the parasite of

A. catalunalis is of great importance and is under further investigation. A study of some species of *Microbracon* (not yet completed) has also shown that in this genus there are enormous variations of size and colouration even within the same species, a fact which does not make the task of separating them easy. The breeding of *Microbracon lefroyi* from the same parent stock in this laboratory for biological purposes has also shown how a long series of specimens, bred under different conditions of temperature and humidity, can vary in colouration and can therefore be useful in accurate specific determinations.

The preparation of lists of all the known Indian species of various insect groups, complete with their systematic and other references, has been continued, and is being published in the series, 'Catalogue of Indian Insects' still in progress. The first catalogue on a parasitic group was published during the year on Chalcidoidea, a second on Evanidae is in press and a third on Braconidae is in course of preparation.

The life-history of *Microbracon brevicornis* Weism. (?) was studied under four constant temperatures, viz., 16°, 25°, 30° and 35°C, in addition to the room temperature. The total period of the life-cycle occupied 35·4, 11·5, 7·5, 5·9, and 6·6 days at the above temperatures respectively. It is interesting to note that this parasite has a higher upper vital limit than *Microbracon lefroyi*. The various hosts from which the parasite was bred included *Antigastra catalaunalis*, *Platyedra gossypiella*, *Earias* spp., *Phthorimoea operculella*, *Laphygma exigua* and *Heliothis armigera*. Adults of this parasite reared at 16°C. are very much darker than those reared at 25°C. and over.

The life-history of a Chalcid, *Prodecatoma* sp., parasitising the weevil, *Microlarinus rhinocylloides* Hochh., was also under study. During July and August the incubation period of this parasite was noted to be about 24 hours, larval period three days, and pupal period four days. The extent of parasitisation was 20—25 per cent. during these two months.

5. IMMATURE STAGES OF INDIAN INSECTS

The study of the immature stages of insects is chiefly carried out in the Insectary where a large number of insects in different stages are under rearing at all times of the year. This is an important part of our work as it helps us in identifying the pests from their younger stages and their mode of attack and also keeps us up-to-date about the varying behaviour of insects in the field during different seasons and years. The results of our work are made available to provincial workers in the form of plates showing the characters of the immature stages of various pests, with the help of which they can distinguish them in the field. Unfortunately the conditions under which the work is carried on is not always satisfactory and during summer, in spite of the best care on the part of the staff, there is usually heavy mortality among the insects in the cages due to the prevailing high temperature in the room. In this way a certain part of the work is always undone and often-times an important insect that has happened to arrive at the adult stage in May or June, after much feeding and care, suddenly succumbs to the heat one afternoon. *Khus* curtains and blinds do not improve the conditions much and the only way out of the difficulty seems to be to 'air-condition' the Insectary.

During the year under report, over eighty different species of insects were under observation for elucidating or noting obscure points in their life-history. Several species such as *Agrotis ypsilon* Rott., *Laphygma exigua*, *Heliothis armigera*, *Tarache notabilis*, *Selepa celtis*, already well known as pests of various crops, show marked colour variations in their larval stages which were drawn in colour to illustrate them. In some cases, e.g., *H. armigera*, the changes of colour resulted from the types of food supplied to the larvae. *Antigastra catalaunalis* Dup., the caterpillars of which rolled and fed on the leaves of *Sesamum indicum*, was reared under conditions of different temperatures and yielded a very interesting parasite of a species of *Microbracon*. The wasp, *Polistes habreanus*, was also under rearing for obtaining its preimaginal stages for study.

6. INSECTICIDES

A study of indigenous insecticides of vegetable origin was undertaken in view of the growing importance of replacing imported mineral insecticides by cheap vegetable poisons easily and abundantly available in this country. Moreover, with the use of the latter, there is very much less risk of poisoning human beings and live-stock than with the former. Among Indian plants with insecticidal properties, the choice fell on *Tephrosia*, a genus with several species well distributed throughout India and with one or two species being very common in certain parts of Bihar and Orissa where it affords a useful preventive measure against soil erosion. It was considered, therefore, that the economic value of *Tephrosia* plants would be further exploited if their seed could be utilised for insecticidal purposes. *T. purpurea* grows commonly in Delhi and flowers practically all the year round. Preliminary experiments have, therefore, been confined to this species and to *T. candida* seeds of which were obtained from Bihar through the courtesy of the Entomologist of the Lac Research Institute, Namkum, Ranchi. With the assistance of the staff of the Imperial Agricultural Chemist, extracts of the toxic principles from the *Tephrosia* plants were prepared in his laboratory by three methods :

Extract I.—A fine powder of seeds (or of leaves) was percolated in cold alcohol for 36-48 hours. This alcoholic extract was partially concentrated on water-bath, then dried in a vacuum desiccator, the alcohol itself being recovered by distillation. A resinous, strongly smelling, very dark brown residue was obtained, which was dissolved in a very small quantity of benzene.

Extract II.—The powder was shaken with 50 per cent. alcohol in a flask and allowed to stand for 24 hours. It was then gently warmed and filtered through a percolation funnel. The alcohol was again recovered from the filtrate by distillation. The residue, left over after it, an aqueous solution, was mixed with 1 per cent. soap solution to the required strength for spraying.

Extract III.—A coarse powder was shaken with water (up to 3 gallons) and the mixture boiled down to 2 gallons over a gentle fire. The resulting fluid after filtration was diluted with water.

Biological tests of the toxic properties of these extracts and also of the leaf and seed dusts on various insects were made in the laboratory and in the field. Control experiments were also performed with some standard

insecticides. The results of the laboratory experiments are given in the following tables :—

TABLE I

Insect.	<i>Tephrosia purpurea</i>			<i>T. candida</i>			Standard insecticide 0·2 0·3 per cent derrisol		
	Extract I			Extract II					
	Per cent mortality in hours			Per cent mortality in hours			Per cent mortality in hours		
	24	48	62	24	48	62	24	48	62
<i>Euproctis lunata</i> . . .	...	...	...	...	...	...	...	...	..
<i>Heliothes armigera</i> . . .	...	...	...	...	...	...	...	...	..
<i>Plusia signata</i> . . .	...	...	...	...	...	...	...	...	..
<i>Plutella maculipennis</i> . . .	Nil	Nil	10	...	...	...	Nil	Nil	15
<i>Brevicoryne brassicae</i> . . .	9	92	...	...	...	...	31	...	...
<i>Myzus persicae</i> . . .	60	71	100	...	...	...	49	77	99
<i>Bagrada picta</i> . . .	50	80	85	4	23	...	25	43	51

TABLE II

<i>Euproctis lunata</i> . . .	100	...	...	89	2	...	...	...	...
<i>Heliothes armigera</i> . . .	40	50	100	51	3	...	...	...	...
<i>Plusia</i> . . .	100	45	12	...	...	...	...	...	...
<i>Plutella maculipennis</i> . . .	...	23	...	...	7	19	...	...	...

As regards the work in the field, both dusting and spraying experiments were done. Powder from the seeds of *T. candida*, mixed with road dust in the ratio of 1 : 2 was dusted on mustard and cabbage plants heavily infested with *Brevicoryne brassicae*. The result showed appreciable reduction in the number of the aphids after 24 hours, but were not conclusive in view of the migration of aphids from the control and other plots. Mustard and cabbage plants infested with aphids and cauliflower plants infested with *Bagrada picta*, sprayed with a 2 per cent. solution of Extract II from the seeds of *T. candida* gave hardly any kill of these insects. Similar trials with 1 per cent. solution of Extract I from *T. purpurea* (in 1 per cent. soap solution) against aphids and *B. picta* were carried out on several vegetable crops. Further trials on a large scale are necessary before reliable conclusions can be drawn.

Some experiments in the control of ants were carried out and further showed the effectiveness of thallium sulphate as a poison in anti-ant baits.

III. SURVEY OF INDIAN INSECT PESTS

Surveys to study the incidence, hosts and food plants, economic status, etc. of various insects were carried out in Delhi and other parts of the country as opportunity permitted.

A. DELHI AREA

At Delhi, the survey of aphids on various crops was continued and resulted in the discovery of about 20 species, the more important of which are the following :—

Aphis maidis Fitch, breeding, in addition to its other hosts, on sugarcane, variety *shakarchinia* ; *A. gossypii* Glover, a polyphagous species, showing great

variations in size and colouration ; *A. sachhari* Zehnt., on sugarcane (at Karnal and ratoon *juar* ; *A. laburni* Kalt on leguminous plants ; *Rhopalosiphum pseudobrassicæ* Davis, at times a serious pest of mustard, rape and *toria* ; *Microsiphum solidaginis* Fabr. (?), large chestnut brown aphid, at times severely infesting safflower.

The survey of ants of Delhi revealed over a dozen species commonly met with in this area, two interesting species, not mentioned in last year's report, being *Polyrhachis simplex* Mayr. collected from under the leaf-sheaths of sugarcane plants and *Colobopsis saundersi* Emery, a rare species collected at light and not recorded before from India.

As in previous years, the appearance and incidence of important insect pests on the estate of the Imperial Agricultural Research Institute and some neighbouring areas was kept under daily observation, and the results of the work are summarized below :—

A. The following insects appeared in pest form during the year :—

Agrotis ypsilon Rott., *A. flammatra* Schiff., caterpillars on gram, safflower, tobacco, carrot and pea.

Laphygma exigua Hb., caterpillars on berseem, lucerne, cow pea and *bajra*.

Heliothis armigera Hubn. caterpillars on pods of gram and pigeon pea. Also noted feeding on many other crops such as *Khesari*, (*Lathyrus sativa*) cabbage, pea and tobacco.

Amsacta moorei caterpillars very severely damaged a large number of crops such as sann-hemp, *Andropogon sorghum*, maize, soy bean, cow pea and *Cyamopsis psoralioides*. They showed special liking for leguminous crops and were the most serious pest in the year. Due to their attack, sometimes crops had to be sown more than once.

Cirphis unipuncta Haw., caterpillars feeding on maize ; also on *khesari* and pea.

Phthorimoea operculella Zell. moths appeared in very large numbers in a godown stored with potato. The larvae were also noted mining leaves of potato in the field : this habit, though common in other countries, has been noted only twice before in India and so far at least as Northern India is concerned, the present observation from Delhi seems to be the first record.

Argyria sticticraspis Hamp. larvae boring in stems of sugarcane.

Plutella maculipennis Curt. caterpillars damaging cabbage, knol kohl. Also noted feeding on radish, turnip and mustard.

Plusia orichalcea Fb. on carrot and gram. Also on several other hosts of which potato and berseem are important. Eggs were also found on these two plants.

Plusia nigrisigna Wlk. on cabbage, lucerne, pea, *khesari*, gram, linseed and sann-hemp.

Antigastra catalaunalis Dup. caterpillars rolling and feeding on leaves of *Sesamum indicum*. Parasitised by *Microbracon brevicornis* Weism. (?) and *Tarytia flavo-orbitalis* Cam.

Earias insulana Boisd. caterpillars feeding on cotton buds and bolls. Also on hollyhock (*Althea rosea*), *Hibiscus esculentus* and some other wild and cultivated plants.

Myzus persicae Sulz. on tobacco. Also noted on a large number of other Solanaceous, Malvaceous and Cruciferous plants.

Cadmilos retiaris Dist. on safflower.

Aulacophora foveicollis Kust on melon, bitter gourd (*Momordica charantia*) and other cucurbits.

Acanthiophilus helianthi Rossi. on safflower. This is the first record of the species and genus of this fruit-fly from India.

Dacus ciliatus Loew., and *D. cucurbitae* Coq., infesting fruits of various cucurbits, specially bitter gourd.

Phytomyza atricornis Meig. maggots mining leaves of *Brassica juncea*, hollyhock, safflower, turnip, spinach (*Spinacea oleracea*) pea, lentil (*Lens esculenta*), carrot, cabbage, wheat and barley.

Emmalocera depressella Swinh. larvae boring underground parts of sugar-cane.

Bagrada picta L. on cabbage, knol kohl, and *Brassica oleracea* var. *boetrytis* and several other plants.

Creontiades pallidifer Dist. on bajra, cow-pea, maize, tobacco, etc.

Urentius echinus Wlk. on brinjal (*Solanum melongena*).

Hypera medicaginis Mshl. on lucerne. Also on potato.

Gryllus sigillatus, common and very troublesome pest in houses.

Gryllulus domesticus L., a household pest and also noted for the first time this year as a minor pest of cotton, nibbling at seedlings at Delhi.

Engytatus tenuis Reut. on tobacco.

B. The following insects noted as pests in 1937-38 occurred in small numbers :—

Euzophera perticella Rag. on *Solanum melongena*.

Euproctis lunata Wlk. on castor.

Empoasca devastans Dist. on *Hibiscus esculentus* and other plants.

Phyllotreta cruciferae Geoz. on cruciferae plants.

B. OTHER AREAS IN INDIA

Outside Delhi, the Section has been mostly surveying the pests of fruits and fruit trees, especially of North India. During the previous two or three years, Baluchistan, North West Frontier Province and the Kulu Valley were visited. Due to the travelling allowance grant of the Section being small, only one area outside Delhi, viz., Kumaun, could be visited during the year for this purpose. In the summer (August and September) of 1938 when the Imperial Entomologist was at Srinagar (Kashmir) on hill recess, the opportunity was utilized for examining orchards in the environs of that locality also. The results of these two surveys are summarized below :—

Kumaun (United Provinces)

In June 1939, the Imperial Entomologist toured the Kumaun hills for 12 days. Orchards near Chaubattia, Ranikhet, Bowali, Bhim Tal and Ramgarh

were examined. The most common fruit-trees in this area are of apple with some peach and plum trees here and there. His observations are summarized below :—

(1) *Root-borer of apple* (*Lophosternus hugelli* Redt.)—This is the most important pest of the area. It is yet not known to be a pest of apple or any other fruit tree outside Kumaun, though it has been recorded to occur in forests on oak in U. P. and Kashmir. In rare cases it also attacks, to a certain extent, the roots of peach and walnut. A single female lays as many as 400 eggs, the rate of mortality in the immature stages is very high and hardly more than 3 per cent. reach the adult stage. However, a single grub is enough to kill a small apple tree. The female starts laying eggs towards the end of June, just after the first showers of rain. Trees growing on dry sandy soils seem to be most highly susceptible to attack by this pest.

(2) *Woolly aphid*.—This pest is also very common all over the area and is active up to the beginning of June and becomes scarce during the monsoon weather. It is again evident during autumn. During June to August, *Coccinella sexpunctata* preys upon this aphid in large numbers.

(3) Defoliating beetles—*Holotrichia longipennis*, *Anomala liveatopennis* and *Melolontha nepalensis* do considerable damage in several parts of the Kumaun Hills by eating away the leaves of apple and other fruit trees.

(4) Apple stem borer (*Zeuzera* sp.)—The caterpillars of this moth tunnel through twigs, shoots and the main stem of apple trees, making them weak and liable to break during strong winds.

(5) Apple aphid (*Aphis pomi*) and the peach aphid (*Anuraphis helichrysis*) are minor pests. It is interesting to record that the green and black peach aphids common in the North West Frontier Province and Baluchistan are not in evidence in Kumaun.

(6) The San Jose scale recently found at Almora and Mussorie was not present in any of the localities visited.

Srinagar (Kashmir)

The following important pests were noted in the orchards within 10 miles radius of Srinagar :—

(1) *San Jose scale*.—This is the most common pest on a variety of host plants including apple, pear, plum, willow, etc.

(2) *Woolly aphid*.—This is also very common. No root form of this aphid has been reported from Kashmir so far. The Coccinellid predator (*Coccinella sexpunctata*) was observed in very small numbers.

(3) Apple skin borer (*Tortrix franciscina*)—causing deep injuries on the skin of the apple fruit.

(4) *Psylla pyricola*, Forst. infesting pear leaves—a minor pest.

(5) *Lecanium corni*.—Apple and other desiduous plants (not walnuts and almonds).

(6) *Lepidosaphes almi* on willow.

(7) *Liparis obfuscata*—a minor pest of fruit trees on willow.

(8) *Brahmina coriacea*, *Adoretus lasiopygus*, *Protactia imparida* P. *reglecta* and *Haltica* sp.—All these beetles defoliate apple, pear and other fruit trees.

(9) *Aeolesthes holoscricea*—boring stems of walnut trees.

Of the pests which were found infesting general crops, grasses, etc., the following were the more important :—

(1) June beetles —*Heteroniceus binodulum*, *Melolontha furcicauda nepalensis* and another species of Melolonthidae.

(2) *Agrotis ypsylon*, *Epilachna 28-punctata* and *E. dodecastigma*.

(3) *Pieris brassicae* and *P. canidia*.

(4) *Scirpophaga* species on maize.

(5) *Plusia* spp.

(6) *Brevicoryne brassicae* on cabbage, etc.

Several other aphids were collected from fruits and vegetables and are yet in the course of identification.

IV. WORK OF THE LOCUST WARNING ORGANIZATION

The work was started on the 1st of April 1939 and has, therefore, been in progress for three months only at the time of writing this report. During this period several extensive surveys were made in the desert areas of Baluchistan, Sind and Rajputana, while intensive local surveys were carried out almost daily in the vicinity of the following outposts in the above areas :—

Pasni, Turbat, Gwadar and Panjgur in Mekran.

Ambagh in the Lasbela State.

Chachro, Barmer, Sukkur, Nokh and Sardarshahr in Sind and Rajputana.

With the wide-spread precipitations received in Mekran during spring, the overwintered adult locusts in the coastal regions became active, bred extensively in May and later scattered themselves into the hinterland areas such as Kulanch and Kalamat-Makola, where a fair amount of breeding was observed during May and June respectively. The maximum locust population in these tracts was about 5,000 per square mile. In Turbat and Panjgur areas some locusts were found, but there was no appreciable breeding. In the coastal areas, especially in the environs of Pasni, a fair amount of breeding of locusts, which had presumably migrated from Kulanch, occurred in June, the maximum population being 1,540 per square mile. In the Hingol area of the Lasbela State active breeding of migrant locusts from Mekran was observed and a population of 5,400 per square mile was found between Chandragup and Kund in June. Owing to a fair amount of rainfall received in North Baluchistan in March and April, the over-wintered adults in the Kachhi area also became active in May. The favourable climate together with the isolated mode of cultivation possible in this area promoted intensive breeding between Bhag and Ghadi, where the population rose up to 19,200 per square mile during June. The locusts collected in this area are being biometrically examined for studying transient tendencies, if any. In the Rajputana desert there was some rainfall in June, and soon after this, a few locusts were found at Nokh (Jaisalmer), Sardarshahr and Bikaner. These were presumably migrants from the winter rainfall tracts, particularly the Kachhi area.

V. INSECT COLLECTIONS

The difficulty of properly housing the collection continues and during summer, a large part of the energies of the staff are spent in saving valuable

specimens from ruin owing to the prevailing high temperatures and dusty atmosphere at times suddenly followed by heavy rain, in spite of all the arrangements of fans and curtains. Even then a certain number of specimens get brittle or mouldy and in course of time break to pieces. The general condition of the collection, therefore, gives much cause for anxiety during at least five months (May to September) of the year. This collection has been gradually built up by the labour of the past thirty years and is now being steadily augmented by the incorporation of new material, reared in our Insectary, collected in fields or obtained from various outside sources, both Indian and foreign. Keeping all the specimens in well made cabinets and air conditioning the collection rooms should remove the difficulties entirely.

During the year under report, about 22,000 specimens, belonging to over a thousand species, were registered, bringing the total registered collection to about 68,000 specimens of about 6,000 species.

The identification of the unnamed material, to which, as remarked last year, additions are constantly being made, was proceeded with and a part of it was named in the Section and incorporated in the collection. This work, however, does not involve merely identification but also the sorting and re-arrangement of the insects into their various groups. As in the previous years, a part of our unnamed material was identified by various outside specialists and institutions whose assistance is gratefully acknowledged. In this connection the Imperial Institute of Entomology, London, has been very helpful. About 250 species, not represented before, have been incorporated in the collection.

In addition to the material reared or collected chiefly at Delhi and some neighbouring areas, general collections of insects of various groups were made in Kashmir and Kumaun hills. Their examination is not completed yet, but it appears that the collections include a number of species and genera not represented in our Collection so far.

The following interesting species were obtained in exchange or in donation, which are thankfully acknowledged :—

Twenty-five species of parasitic Hymenoptera (exchange) from the Director, Deutsches Entomologisches Institut, Berlin-Dahlem.

Ten species of ants from Mr. A. Mallis, Los Angeles, California (exchange).

Five species of British ants from Mr. W. Pickles through Miss Ellen Gallway of Huddersfield Museum.

Specimens of *Rhaconotus oryzae* Wilk., from the Entomologist to Government, Punjab.

Five species of Braconidae from the Forest Entomologist, Dehra Dun.

A large number of specimens of locusts and other Orthoptera from the Locust Research Laboratory, Karachi, consequent upon the transfer of the work on locust surveys from the Imperial Council of Agricultural Research to the Government of India.

Named insects from our Collection were donated to the following :—

Mr. W. V. Harris, Entomologist, Tanganyika Territory. (Termites).

The Forest Entomologist, Dehra Dun (Coleoptera).

Entomological Assistant, Jullundur (Fruit-flies).

The Principal, Cambridge School, Delhi (Common pests).

The Sugarcane Entomologist, Bihar Department of Agriculture, Pusa (Pests of sugarcane).

Immature stages of the wasp, *Polistes habraeus* to Mr. D'Rozario, Zoological Laboratory, Cambridge University, for study.

Some identified species of *Xylocopa* were loaned to the Director, Zoological Survey of India, Calcutta, for study by a student there.

During the year, the rearrangement of the species in the groups Chalcidoidea, Braconidae and Formicidae was completed, and the sorting out and identification of unnamed material of several families of Rhynchotha and Microlepidoptera was in hand. Due to rapid advances in taxonomic work in different parts of the world, the names and classification of old species are under constant revision. Checking of the scientific names of the species represented in the collection, and their systematic position under various groups, with a view to keeping them up to date forms an important part of the work of the staff.

VI. ADVISORY

1. IDENTIFICATION OF INSECTS

About 30 consignments of insect specimens comprising about 275. different species (as compared with 70 species last year) were received from various parts of India and neighbouring countries and identified as far as possible. Some of the more important identifications, other than those of parasites, are given below :—

Eublemma parva and *Pseudococcus filamentosus* var. *corymbatus* on " *Xanthium* sp. from Mr. Mundell, Entomologist, " *Xanthium* " Investigation, Commonwealth of Australia ;

Podops coarctata Fab., from the Entomologist to Government, Burma.

Rhalidophaga mungifera attacking mango twigs, from the State Entomologist, Cochin.

Aspidiotus perniciosus and *Phenococcus*, sp., on mango and other deciduous plants, from the Entomologist, United Provinces, Cawnpore.

2. INFORMATION ABOUT INSECT PESTS AND PARASITES

About 100 enquiries were received and answered from correspondents in India and abroad about the distribution, biology and control of insect pests and parasites, of which the more important are summarized below :—

Distribution of Hymenopterous parasites of *Margaronia caesalis* to the Chief Entomologist, Ceylon.

Information about the pests of mango, grape-vine, flax, berseem, pineapple, etc., and advice on the control of black ants, wasps, termites, stored grain pests to various correspondents all over India.

Information on the possibility of using *Trichogramma minutum* (Riley) in the control of insect pests of cotton, was supplied to the Indian Central Cotton Committee.

A statement of important pests which have come into prominence in India during recent years and the methods of controlling them, as well as a list of important references to literature on Indian insect pests published during the last ten years, were supplied to the Imperial Council of Agricultural Research for the use of the United States Department of Agriculture.

A summary of the work on sericulture done in this Institute was supplied to the Director of Industries, Bombay.

Complete information available was given to the Imperial Council of Agricultural Research about food-plants of San Jose scale and the methods of fumigating infested material and suggestions were made about legislative measures to prevent its spread from one province to another.

A summary of measures taken by the Government of India to prevent the introduction of the Mediterranean fruit-fly, *Ceratitis capitata* into the country, was supplied to the Imperial Council of Agricultural Research.

Full particulars about the parasites of *Pseudococcus comstocki* in India were supplied to Mr. H. Kallenbach of South Africa. Detailed notes on the biology in India of four lepidopterous pests attacking pigeon pea in Mauritius were supplied to the Director of Agriculture, Mauritius.

A list of important references to papers on the ecology of the house-fly was supplied to the Professor of Zoology, University of Lucknow.

The breeding of flies in the night-soil silt-beds at Kilakori Sewage Farm near New Delhi was examined at the request of the Public Health Commissioner with the Government of India. As a result of some experimental work, advice was given about the thickness to which silt should be laid so as not to encourage fly-breeding.

A consignment of cotton seeds imported by the Government of Afghanistan from the United States of America, was examined and fumigated at Bombay.

BEE-KEEPING

Over 110 enquiries (as compared with 70 for the last year) were received from different parts of India, relating to literature on bee-keeping, bee-keeping appliances, the importation of foreign bees, bee diseases, composition and food value of honey, bee stings and economic possibilities of *Apis dorsata*. Advice was given to several correspondents about starting bee-keeping.

The demand for comb-foundation wax sheets and queen excluder zinc sheets was very much greater than before, to meet which over two maunds of foundation sheets were made.

VII. MISCELLANEOUS

Anti-malaria operations on the estate of this Institute were supervised and mosquito-breeding kept in check. The following species were observed breeding in different situations :—*Anopheles subpictus* Grassi and *A. culicifacies* Giles in irrigation channels, rain water pits, storm water drains, etc. ; *Culex fatigans* Wied. in sludge-water tanks and dirty collections of water in the drains of laboratories, and *Aedes vittatus* Bigot in quarries and ant channels around laboratory buildings.

A campaign to reduce the fly nuisance on the Institute premises was carried on practically throughout the year and intensified during spring and autumn, or when the Horticultural Department dumped manure on the lawns of the Estate and the fly-breeding was consequently noticed to be on the increase. In this connection the fly trap designed in this Section a few years ago was found to be very effective. It is also gratifying to record that the Assistant Public Health Officer, New Delhi, is adopting the use of similar traps in the town.

VIII. PROGRAMME FOR 1939-40

Research work will be continued on the same lines as during 1938-39. In addition it is proposed to start work on the bionomics of honey bees. Regarding survey of pests outside Delhi, particular attention will be paid to fruit pests, especially in the hill tracts of North India.

REPORT OF THE SECOND ENTOMOLOGIST (DIPTERIST)

IN-CHARGE OF

SCHEME* FOR RESEARCH ON INSECT PESTS OF SUGARCANE

(P. V. ISAAC)

1. OBSERVATIONS ON MAJOR PESTS

The major pests at New Delhi were *Argyria sticticraspis* Hmps., *Raphimetopus ablutella* Zell., and *Emmalocera depressella* Swinh., in the early part of the year. *Scirpophaga nivella* F., appeared when the plants had formed stalks and was active during the rest of the life of the crop. *Pyrilla* spp., was only in small numbers. In Karnal the major pests were *Scirpophaga nivella* F., *Argyria sticticraspis* Hmps., important in early life of the crop and *Emmalocera depressella* Swinh. Those found in small numbers are *Raphimetopus ablutella* Zell., *Chilo zonellus* Swinh. *Sesamia* sp. and *Pyrilla* spp. Varietal studies showed on statistical analysis that Co. 331 was the most resistant to Top-borer. In Pusa the main pests were *Scirpophaga* spp., *Argyria sticticraspis* Hmps., *Diatraea auricilia* Dudgn., and *Emmalocera depressella* Swinh. Variety Co. 331 was found to be more resistant than Co. 210 to attack by *Scirpophaga* spp. *Pyrilla* spp., was found in small numbers. In Coimbatore field observations were made on *Scirpophaga nivella* F., present throughout the year, *Argyria sticticraspis* Hmps., abundant during the pre-monsoon months and *Diatraea venosata* Wlk., abundant in the latter half of the year. *Sesamia inferens* Wlk., a pest of *ragi* was found during March to July in Sugarcane shoots. A new borer similar to the new Pyralid borer in Gurdaspur appeared in the Dehra Dun area. Spraying an emulsion of one ounce of kerosine oil and one ounce of soap in one gallon of water against *Pyrilla* in a crop about three feet high checked the pest in an area of three and a half acres at a cost of Rs. 3-11-0 per acre.

2. COLLECTION OF NATURAL ENEMIES

Several natural enemies were collected or reared out.

3. BIOLOGICAL CONTROL

(a) *Laboratory studies*.—(1) *Lestodryinus pyrilla* Crawf., a nymphal parasite of *Pyrilla* spp. This parasite attacks the pest in the early stages of its development and thus prevents it from doing any material damage to the crop. It could be reared easily in the laboratory and it is a parasite which deserves encouragement. A parasitized nymph ceases to grow and as the development of the parasite advances the pest nymph becomes more and more lethargic in its habits. (2) *Ageniaspis pyrilla* Mani, *Tetrastichus pyrilla* Crawf., and *Cheiloneurus pyrilla* Mani,—A comparative study was made of the bionomics of these three egg parasites of *Pyrilla* spp. They appear in the field during the crop season in the order in which they are given; *Ageniaspis pyrilla* Mani, and *Tetrastichus pyrilla* Crawf., parasitising eggs laid on leaves during late summer and autumn and *Cheiloneurus pyrilla* Mani, parasitizing eggs laid in leaf sheaths during winter. All the three are very

*This represents a summary of the full report submitted to the Imperial Council of Agricultural Research who finance the scheme.

useful parasites and capable of rendering valuable service to the cane grower. (3) *Chrysopa* sp.—a predator on the eggs and nymphs of *Pyrilla* spp. It is capable of exercising an appreciable control on the population of this pest and during off season it could be successfully reared on aphids of different species. (4) *Apanteles flavipes* Cam.,—a parasite of the stem borer *Argyria sticticrasis* Hmps. It parasitizes *Diatraea venosata* Wlk., and *Sesamia uniformis* Dudgn., also and could be used to control these three stem borers.

(b) *Biological Control field operations.*—Mass liberations of *Trichogramma minutum* Riley against the stem borer *Argyria sticticrasis* Hmps., were conducted at Cuttack and Banki in Orissa and at Lalseriya and Madhopore in Bihar. There is dependable evidence to show that this parasite does exercise a considerable check on the stem borer and contributes to higher yields. Conservation of the egg parasites of *Pyrilla* spp., from stripped plots was tried at Palhera farm with satisfactory results. Parasitized egg masses collected from stripped leaves were conserved in wire gauze cages which were distributed over the infested area. Emerging parasites escaped into the field while emerging nymphs of the pest were imprisoned in the cage.

4. COLLATION OF INFORMATION FROM PROVINCES AND STATES

Information for 1938 was collected and collated for submission to the Imperial Council of Agricultural Research.

5. BIONOMICS OF PESTS

Sesamia uniformis Dudgn., was found to have in New Delhi an egg period of five days, larval period of 17 to 41 days with six instars and a pupal period of 8 to 10 days and adult life of five to seven days during May and June. A single moth in this season lays 32 to 36 eggs. *Scirpophaga* spp.—The larva was found to bore first into the mid-rib through which it tunnels to the leaf base from whence it bores into the shoot. The mid-rib in varieties resistant to this borer was found to be harder than in those varieties that were susceptible and the hardness seemed to be due to higher silicification and lignification in certain sets of plant cells. Anatomical studies of several borers were attended to.

6. REGIONAL SURVEY OF SUGARCANE BORER POPULATIONS

This work was started and instructions were sent to the seventeen Regions selected and their periodical reports were examined.

APPENDIX I

Gazetted Staff of the Institute

		Remarks
Director . . .	Rao Bahadur B. Viswa Nath.	
Joint Director . . .	Mr. M. Wynne Sayer.	
Agriculture		
Imperial Agriculturist . . .	Mr. M. Wynne Sayer . . .	} On Mr. Sayer proceeding on leave from 5th May, 1939. Mr. Arjan Singh was placed in charge of the Section.
Assistant Agriculturist . . .	Mr. Arjan Singh . . .	
Statistician . . .	Mr. P. V. Krishna Iyer.	
Farm Superintendent, Karnal .	Mr. A. R. Khan.	
Cattle Superintendent, New Delhi.	Vacant.	
Cattle Superintendent, Karnal .	Mr. S. M. Jamaluddin.	
Engineering Assistant . . .	Mr. A. K. Kaul.	
Botany		
Imperial Economic Botanist .	Dr. B. P. Pal.	
Second Economic Botanist .	Dr. S. Ramanujam.	
Assistant Economic Botanist .	Rai Sahib Kashi Ram.	
Superintendent, Botanical Sub-station, Pusa.	Mr. R. D. Bose . . .	The post is temporary.
Special Research Assistant .	Mr. R. B. Deshpande (Offg.) .	The permanent incumbent is Mr. R. D. Bose.
Agricultural Chemistry and Soil Science		
Imperial Agricultural Chemist .	Rao Bahadur B. Viswa Nath.	
Assistant Agricultural Chemist.	Mr. J. N. Mukerji.	
Assistant Agricultural Bacteriologist.	Mr. N. V. Joshi.	
Second Assistant Agricultural Bacteriologist.	Dr. S. V. Desai.	
Assistant Sugarcane Chemist .	Mr. S. Chaudhuri . . .	The post is temporary.
Entomoy		
Imperial Entomologist . . .	Dr. H. S. Pruthi.	
Second Entomologist (Dipterist)	Mr. P. V. Isaac.	
Biological Control Research Officer.	Dr. J. A. Muliyl . . .	The post is temporary.
Assistant Entomologist . . .	Dr. Taskhir Ahmad.	
Second Assistant Entomologist	Dr. K. B. Lal.	
Assistant Locust Entomologist	Mr. H. L. Bhatia (Offg.).	
Superintendent, Locust Sub-station, Karachi.	Dr. S. Mukerji (Offg.).	

Mycology and Plant Pathology

Imperial Mycologist	. . .	Dr. G. Watts Padwick.	
Assistant Mycologist	. . .	Dr. M. Mitra.	
Second Assistant Mycologist	. . .	Dr. B. B. Mundkur.	
Plant Pathologist for Sugarcane Diseases.	Dr. B. L. Chona	. . .	The post is temporary.
Assistant Sugarcane Mycologist	Mr. L. S. Subramaniam	. . .	The post is temporary.

Sugarcane Station, Coimbatore

Sugarcane Expert	. . .	Rao Bahadur T. S. Venkataraman.	} During Rao Bahadur's leave for 3 months from 24th March, 1939, Mr. Dutt officiated as Sugarcane Expert.
Second Cane Breeding Officer	. . .	Mr. N. L. Dutt	
Assistant Sugarcane Expert	. . .	Mr. R. Thomas.	
Geneticist	. . .	Dr. (Miss) Janaki Ammal	. The post is temporary. Dr. Janaki resigned from 25th May, 1939.

APPENDIX II

Training of Students and Research Workers during 1938-39

(a) Awarded Post-graduate Diploma of the Institute

Name	Subject of Thesis
1. S. Solomon (Bombay) .	The Experimental Production of Polyploids.
2. T. Narayan Rao (Madras) .	Part I.—Flower and Seed Production in Gram. Part II.—Ovule Mortality in Gram.
3. K. K. Khosla (Patiala State)	Correlation Studies in Linseed.
4. B. Rama Moorthy (Madras) .	A New Carbon-Nitrogen relationship in Nature.
5. S. K. Mukerji (Bengal) .	A Study on the Composition of Colostrum and Premilk of some Cows.
6. P. Attmaraman (Madras) .	Extraction of Soil Solutes and Studies in their Composition.
7. M. A. Azeez (North-West Frontier Provinces).	Some Physical Properties as Factors in Evaluating the Soil Characteristics.
8. Nirankar Prasad (United Provinces).	Studies on the Wilt of Gram.
9. R. L. Gupta (Central Provinces).	Part I.—The Leaf-miner, <i>Phytomyza atricornis</i> , Meigen. Part II.—Review of some Important Pests of Vegetable Crops of Northern India.
10. P. L. Kohli (North-West Frontier Province).	Sugarcane Breeding at Coimbatore.

(b) Awarded Post-graduate Certificate in Agriculture

1. K. H. Sujansingani (Sind).
2. M. Aijaz Husain (United Provinces).
3. Biswanath Das (Orissa).
4. Sardar Mohammad (Punjab).
5. Atar Singh (United Provinces).

(c) Post-graduates under training during the year

Name	Subject	Date of admission
1. Khan Mohd. Khan (North-West Frontier Province).	Agriculture . . .	November, 1933.
2. H. D. Naithani (United Provinces).	Ditto . . .	Ditto.
3. Kh. Sadiq Husain Ansari (Punjab).	Ditto . . .	Ditto.
4. J. C. Chakravarty (Assam) .	Ditto . . .	Ditto.
5. M. C. Joshi (Ajmer-Merwara)	Ditto . . .	February, 1939.
6. R. M. Arora (United Provinces).	Botany . . .	November, 1937.
7. A. B. Joshi (Central Provinces).	Ditto . . .	Ditto.
8. S. L. Juneja (Punjab) . .	Ditto . . .	Ditto.
9. G. S. Murty (Madras) . .	Ditto . . .	Ditto.
10. M. J. Deshmukh (Central Provinces).	Ditto . . .	November, 1938.

(c) Post-graduates under training during the year—*contd.*

Name	Subject	Date of admission
11. Mohd. Jafar (Hyderabad State).	Botany . . .	November, 1938.
12. Y. R. Mehta (United Provinces).	Ditto . . .	Ditto.
13. H. C. Mirchandani (Sind) .	Ditto . . .	Ditto.
14. M. P. Narasimha Rao (Madras).	Ditto . . .	Ditto.
15. Harbhajan Singh (Punjab) .	Ditto . . .	Ditto.
16. Abhisheswar Sen (Bengal) .	Agricultural Chemistry .	November, 1937.
17. W. V. B. Sundara Rao (Madras).	Ditto . . .	Ditto.
18. T. C. Gidwani * (Sind) . .	Ditto . . .	Ditto.
19. K. C. Batra (Punjab) . . .	Ditto . . .	November, 1938.
20. K. M. Mehta (Jodhpur State)	Ditto . . .	Ditto.
21. N. G. C. Iyengar (Mysore State).	Ditto . . .	Ditto.
22. Viswanath Prasad (Bihar) .	Ditto . . .	Ditto.
23. A. P. Kapur (Baluchistan) .	Entomology . . .	November, 1937.
24. C. B. L. Bhargava (Ajmer-Merwara).	Ditto . . .	Ditto.
25. P. L. Chaturvedi (United Provinces).	Ditto . . .	November, 1938.
26. Z. A. Siddiqi * (Bhopal State)	Ditto . . .	Ditto.
27. S. N. Elijah (Bombay) . .	Ditto . . .	Ditto.
28. R. S. Mathur (United Provinces).	Mycology . . .	November, 1937.
29. S. Y. Padmanabhan (Madras)	Ditto . . .	Ditto.
30. P. R. Bhagwagar (Central Provinces).	Ditto . . .	November, 1938.

(d) Short Courses

Name	Subject	Period of stay
1. Kirti Kar (United Provinces).	Plant breeding technique.	Two months.
2. A. S. Sastry (Madras) . . .	Sugarcane and soil analysis	Four months.
3. M. Patnaik (Department of Agriculture, Orissa).	Ditto	Seven months.
4. K. B. Shome (Bengal) . . .	Ditto	Five months.
5. S. P. Ray Chaudhury (Dacca University).	Plant pathological technique	One month.
6. R. A. Bhote (Barwani State, Central India).	Principles of applied entomology	Under training.
7. Indra Sinha (Dairy Farm, Montgomery).	Cattle management and calf rearing.	Two weeks.
8. Kartar Singh (His Excellency the Viceroy's Body Guard Dairy).	Ditto	One month.
9. Dafadar Jahan Khan (His Excellency the Viceroy's Body Guard Dairy).	Ditto	Two weeks.

* Left, before completion of course, to take up appointments.

NOTE.—Besides the above, three officers of the *Gur* Development Scheme in the United Provinces made a critical study of the process of manufacture of active carbon.

(e) **Honorary Research Workers**

Name	Subject of research	Remarks	
1. S. Narayan Swamy (Madras).	Megasporogenesis and the origin of triploids in <i>Saccharum</i> .	Awarded degree Madras university.	M.Sc. by Uni-
2. P. Abraham (Indian Central Cotton Committee).	Cytology of three Asiatic cottons and the interspecific hybrid <i>G. arboreum</i> × <i>G. Stocksii</i> .		
3. B. Ramamoorthy (Madras)	Reciprocal relations of carbon and nitrogen fixation in biological system.		
4. S. V. Ramanayya (Madras)	Anthocyanin pigments in sugarcane.		
5. N. N. Chopra (Punjab University).	Biochemistry of pigment formation by an indigenous strain of <i>Penicillium</i> mold and biochemistry of enzymic protein hydrolysis and synthesis.		
6. B. T. Mulwani (Sind)	Effect of added soluble salts on soil solution and base exchange.		
7. V. P. Rao (Hindu University)	Taxonomic studies of Indian Coccidae, specially those of Baluchistan.		
8. Gobind Ram Shah (Government College, Lahore).	Aphides of the Delhi Province.		
9. S. S. Kapur (Punjab University).	Studies in Orthoptera.		
10. S. Sinha (Lucknow University).	Identification of fungi.		
11. Dr. Mathur (Punjab University).	Preparation of glucose from starch.		

APPENDIX III

List of papers published during 1938-39

1. Bose, R. D. and Misra, S. D. Studies in Indian fibre plants, No. 6 phyllody and some other abnormalities in the flower of sunn-hemp. *Indian J. agric. Sci.*, 1938, **8**, 417-27.
2. Bose, R. D. The rotation of tobacco for the prevention of wilt disease in pigeonpeas [*Cajanus Cajan* (Linn.) Milsp.]. *Agric. Live-Stk. India*, 1938, **8**, 653-68.
3. Deshpande, R. B. Studies in Indian chillies (5). Inheritance of another colour and its relation to colour in petal and node in *Capsicum annum* L. *Indian J. agric. Sci.*, 1939, **9**, 185-92.
4. ————— A Note on the occurrence of a chlorophyll deficiency in linseed (*Linum usitatissimum* L.). *Curr. Sci.*, 1939, **8**, 168-69.
5. Dutt, N. L., Krishnaswamy, M. K. and Subba Rao, K. S. On certain floral characters in Sugarcane I. *Proc. int. Soc. Sugarcane Tech. 6th Cong.* 1939, pp. 154-170.
6. Dutt, N. L. Certain suggested floral characters for distinguishing commercial sugarcane varieties. Paper read at the Agril. Section of the Ind. Sci. Cong. 1939 (Lahore).
7. Hussainy, S. A. Technique of Sugarcane $\times$ Bamboo pollination. *Curr. Sci.*, **7**, 5, 1938, p. 232.
8. Janaki Ammal, Dr. E. K. A Sachharum $\times$ zea cross. *Nature* 142: 618-19.
9. ————— Triplo-polyploidy in *S. spontaneum*. *Curr. Sci.* Vol. **8**, 2 Feb. 1939, pp. 74-76.
10. Lal, K. B. Parasitism in Insects. *Curr. Sci.*, **8**, No. 2, 1939.
11. ————— Phytopathology Entomology. *Ann. Rev. biochem. allied Res. India*, **9**, 1938.
12. ————— Identity of two Important Parasites hitherto considered as distinct species. *Curr. Sci.*, , No. 3, 1939.
13. Mani, M. S. Studies on Indian Itonidae. *Rec. Indian Mus.*, **40**, Pt. IV, 1938.
14. ————— *Catalogue of Indian Insects*, Pt. 24, Evanidae.
15. Mundkur, B. B. A contribution towards a knowledge of Indian Ustilaginales. Fragments I-XXV. *Trans. Brit. mycol. Soc.*, **23**, 86-121, 1939.
16. ————— Phytopathology-Mycology in 1938. *Ann. Rev. biochem. allied Res. India*, **9**, 110-123, 1939.
17. Mundkur, B. B., and Prasad, N. On a new *Ravenelia* from India. *Mycologia*, **30**, 685-688, 1938.
18. Padwick, G. W. The Genus *Fusarium*. I. Known occurrence in India. *Indian J. agric. Sci.*, **9**, 171-184, 1939.
19. Pal, B. P. Problems of potato breeding in India. *Agric. Live-Stk. India*, 1938, **8**, 388-96.
20. ————— A brief note on the seed supply of Virginia tobacco. *Agric. Live-Stk. India*, 1939, **9**, 42-43.

21. Pal, B. P., and Pushkar Nath . Shortening the rest period of the potato (*Solanum tuberosum* L.). *Indian J. agric. Sci.*, 1938, 8, 777-86.
22. Pal, B. P., and Ramanujam, S.. Induction of polyploidy in chilli (*Capsicum annum* L.) by colchicine. *Nature*, 1939, 143, 245-46.
23. Pal, B. P., and Mundkur, B. B. Studies in Indian cereal smuts : I. Cereal smut and their control by the development of resistant varieties. *Proc. Indian Acad. Sci.*, 1939, 9, 267-70.
24. Prasad, H. H. A note on soft rot of pears caused by a species of *Aspergillus*. *Indian J. agric. Sci.*, 8, 549-51, 1938.
25. Prasad, N., and Padwick, G. W. The Genus *Fusarium*. II. A species of *Fusarium* as a cause of wilt of gram (*Cicer arietinum*). *Indian J. agric. Sci.*, 9, 371-80, 1939.
26. Pruthi, Hem Singh, and Batra, H. N. A Preliminary annotated list of the fruit pests of the North-West Frontier Province. *I. C. A. R., Miscellaneous Bull.*, 10, 1938.
27. ————— The Phytophagous chalcidoid, *Eurytoma samsonowi* Vas.—a serious pest of apricot and some other fruits in India. *Indian J. agric. Sci.*, 9, Pt. 2, 1939.
28. Pruthi, Hem Singh, and Bhatia, H. L. Biology and general morphology of *Leucopis griseola* Fall., and important predator of *Aphis gossypii* and some other aphid pests of crops. *Indian J. agric. Sci.*, 8, Pt. 5, 1939.
29. Pruthi, Hem Singh, and Narayanan, E. S. A statistical study of the damage done by borers to sugarcane at Pusa. *Indian J. agric. Sci.*, 9, Pt. 1, 1939.
30. Pruthi, Hem Singh The distribution, status and biology of Codling moth in Baluchistan. *Indian J. agric. Sci.*, 8, Pt. 4, 1938.
31. Ramanayya, S. V., and Satyanaraya, K. A study of the filterability of Co. 213, sugarcane sulphitation scums—the nature of non-sugars in relation to filtration. *Proc. 7th Ann. Convention, The Sugar Technologists Assn., India*, 1938.
32. Sayer, Wynne The influence of Skeletal Alterations on the Milch Qualities of the Sahiwal Breed. *Agric. Live-Stk. India*, 8, 1938, 541-46.
33. ————— Tyre Life in Pneumatic Outfits for Bullock Carts, *Agric. Live-Stk. India*, 9, 1939, 53-5.
34. ————— Cattle Research in India—experiments with the famous Sahiwal herd. *The Statesman Horse & Cattle Show Supplement*, Feb. 13, 1939, 5.
35. ————— Use of Machinery in Agriculture—a limited field. *The Times Trade and Engineering*, 44, No. 902 (New series) April, 1939, xlv.
36. Solomon, S. Hybrid vigour in plants and its significance in plant breeding and agriculture. *Agric. Live-Stk. India*, 1939, 9, 1939-48.
37. Venkatraman, T. S. . . . Cane hybridization work in Coimbatore. *Proc. int. Soc. Sugarcane Tech. 6th Cong.* 1939, 731-32.

38. Viswa Nath, B. . . . Organic Manures and a new cycle of accessory factors in nature. *Proc. Soc. biol. Chemists, India.*
39. ————— . . . The utilization of agricultural and human wastes by composting. *Indian Science Congress, 1939.*
40. ————— . . . Irrigation and Soil deterioration. *Indian Science Congress, 1939.*
41. ————— . . . On black and red soils of India. *Proc. nat. Inst. Sci., India, 1939.*

